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6. AUTHOR(S) Ross L. Bell		
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ANTENNA PRODUCTS

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25 September 1998

Defense Technical Information Center (DTIC)
Cameron Station
Alexandria, VA 22304-6145

Attention: DTIC-OC

Subject: Technical Report Number 0910-1093

Reference: Contract DAAB07-97-C-D609

Subject:

Enclosed are two copies of the approved technical report delivered under the above referenced contract. As also required per the contract, A standard Form 298 is attached to each copy of the report.

Should there be any questions please contact the undersigned.

Sincerely,

Tina Cooper

Tina Cooper
Contracts Administrator

enclosures

12 a. DISTRIBUTION / AVAILABILITY STATEMENT	12 b. DISTRIBUTION CODE
Approved for public release; distribution unlimited.	

13. ABSTRACT (Maximum 200 words)

The purpose of this program is to design, build, test and deliver a VHF-UHF fixed station mast mounted antenna system. Antenna Products proposed three configurations to investigate in an effort to achieve an acceptable system.

Configuration A consisted of combining a VHF monopole/counterpoise antenna and a UHF collinear antenna. During the investigation it was found that the counterpoise did not properly terminate the radiating structure when the radials are less than a quarter wavelength long. The performance is characterized by a loss of gain at the lower frequencies. A full size structure would be larger and heavier than a dipole antenna. Therefore, no further investigation of configuration was undertaken.

Configuration B consists of combining a VHF vertical half-rhombic antenna system and a UHF collinear antenna. The rhombic antenna system was envisioned as two rhombic curtains mounted orthogonally about a 10 meter mast and would serve as guys for the mast. The UHF antenna would mount on top of the mast. It has been determined that to achieve reasonably omnidirectional azimuth patterns it is necessary to use four rhombic curtains in an azimuth array. At the interim report, the height of the antenna was 10 meters and the radius was 25 meters. Further investigations have lead to a 10 meter tall structure with 10 meter radius that uses six equally spaced slant wires that are fed in-phase near ground and connected at the top of the tower. A UHF collinear dipole array mounts on top of the dielectric mast. A prototype of this antenna is available for shipment to CECOM for further evaluation.

The propagation mode for this antenna is surfacewave instead of spacewave as commonly experienced when two antennas are mounted on masts above the earth's surface. Therefore, field tests should be conducted to determine the suitability of the antenna for the application.

Configuration C consisted of incorporating a UHF monopole/counterpoise antenna into a VHF monopole/counterpoise. Following the investigation of configuration A, the configuration was changed to dipole radiators and the monopole/counterpoises were eliminated.

Although initial efforts were encouraging, internal resonances haunted the matching of a structure within a structure approach. In view of this, the approach was changed once again to a structure around a structure much like the SB-201 in which UHF dipoles are mounted around ships masts and yet provide omnidirectional azimuthal patterns. Unfortunately, time and funds expired before these efforts could be completed.

14. SUBJECT TERMS	15. NUMBER OF PAGES
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	16. PRICE CODE

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UNCLASSIFIED	**UNCLASSIFIED**	**UNCLASSIFIED**	**UL**

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UNCLASSIFIED

APC REPORT NUMBER: 0910-1098

May 27, 1998

FINAL STATUS REPORT

VHF-UHF FIXED STATION MAST MOUNTED ANTENNAS SYSTEM

PREPARED FOR:
U.S. ARMY CECOM ACQUISITION CENTER
FT. MONMOUTH, NJ
CONTRACT NO. DAAB07-97-C-D609

ANTENNA PRODUCTS
101 S.E. 25th Avenue • Mineral Wells, Texas 76067
Phone 940/325-3301 • Fax 940/325-0716

UNCLASSIFIED

CECOM Acquisition Center
Ft. Monmouth, NJ

Contract: DAAB07-97-C-D609
May 27, 1998
Final Technical Report

VHF-UHF FIXED STATION MAST MOUNTED ANTENNA SYSTEM

by

ANTENNA PRODUCTS CORPORATION
Mineral Wells, Texas

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Summary

The purpose of this program is to design, build, test and deliver a VHF-UHF fixed station mast mounted antenna system. Antenna Products proposed three configurations to investigate in an effort to achieve an acceptable system.

Configuration A was terminated in December 1997.

Configuration B consists of combining a VHF vertical half rhombic antenna system and a UHF collinear antenna (DPV-51). The initial VHF antenna system consisted of two rhombics mounted orthogonally about a 10 meter mast and serve as guys for the mast. The UHF collinear antenna mounts on top of the mast. The original concept was to feed the two rhombic curtains 90 degrees out of phase to achieve a more nearly omnidirectional azimuth pattern. At the time of the interim report, four curtains were required in an azimuth array in order to achieve a reasonable omnidirectional pattern. Since that time the four rhombics were reduced to three and then the structure was changed to six equally spaced slant wires all fed in-phase. The ground radius of the slant wires was reduced to 10 meters from 20 meters. The predominant propagation mode is surfacewave instead of spacewave as encountered when two dipoles are mounted above ground and separated several miles. As a first priority, it is recommended that the range of the antenna be determined through field tests.

The modifications to the DPV-51 were made and have been reported.

Configuration C consists of incorporating a UHF monopole/counterpoise antenna into a VHF monopole/counterpoise. Following the investigation of configuration A, it was felt that this configuration should be changed to dipole radiators and that both monopole/counterpoises should be eliminated. Some effort has been expended on this revised approach prior to the interim report with some encouraging results. Following the interim report the integration of the complete antenna revealed multiple resonances and the structure was eventually changed a second time to reflect wrap around UHF dipoles and a single VHF dipole. Time and funds prevented the completion of this investigation. It is recommended that this effort be continued as part of a future study.

1.0 INTERIM STATUS

1.1 Configuration A

Antenna Products made a unilateral decision to terminate efforts on configuration A. Following the review of the interim report CECOM agreed with this decision.

1.2 Configuration B

Investigations of configuration B continued following the interim report. The structure evolved to a circular array of six slant wires connecting between ground and the top of a 10 meter mast. A prototype antenna, matching units and combiner were built and tested. CECOM personnel inspected the erected antenna.

1.3 Configuration C

Configuration C has been changed a second time to reflect an antenna wrapped around a second antenna (or mast). This is a technique commonly used on US Naval vessels. The results are encouraging; however, the investigation was not completed since both time and funds were depleted.

2.0 FUTURE PLANS

2.1 Configuration B

An engineering prototype has been built, tested and shipped to CECOM. The azimuth pattern was improved somewhat over the frequency band in the final configuration and it was determined that the mast needs to be dielectric. It is recommended that tests be conducted to determine the range of the antenna.

2.2 Configuration C

This configuration appears promising; however, it requires further investigations in order to match the antenna impedances and determine the gain of the integrated structure.

3.0 LABOR AND COSTS

The accumulated labor on this contract is tabulated in Table 3.1. There have been 529 engineering hours, 8 drafting hours, 7 assembly hours, and 668 technical support hours spent. Materials to date total $1219.54. The total cost so far without profit is $47,244.05. These costs exceed our $35,000 contract.

4.0 DELIVERY

Configuration B prototype has been shipped to CECOM. The technical report has been submitted. No further effort is anticipated under this contract.

5.0 REPORT PREPARER

This report and the technical report were prepared by Ross L.Bell, Research and Development Manager with cost inputs from Ron Chandler, Vice President of Marketing. Both can be reached at (940) 325-3301.

Page No. 1 Monthly Jobcard Summary
05/27/98

Week of	Clock No.	Home Dept	Work Order No.	Dept Worked On	Hours
** Work Order			080610		
* Dept Worked 601					
06/20/97	3	601	080610	601	6.00
07/11/97	3	601	080610	601	8.00
08/01/97	3	601	080610	601	8.00
07/25/97	3	601	080610	601	10.00
08/08/97	3	601	080610	601	24.00
01/09/98	3	601	080610	601	4.00
01/23/98	3	601	080610	601	12.00
05/22/98	117	601	080610	601	2.00
05/22/98	3	601	080610	601	10.00
08/15/97	3	601	080610	601	15.00
08/22/97	3	601	080610	601	4.00
01/16/98	3	601	080610	601	6.00
05/15/98	3	601	080610	601	6.00
08/29/97	3	601	080610	601	28.00
09/05/97	3	601	080610	601	10.00
09/12/97	3	601	080610	601	20.00
04/17/98	3	601	080610	601	8.00
09/19/97	3	601	080610	601	20.00
05/08/98	3	601	080610	601	17.00
04/10/98	3	601	080610	601	4.00
09/26/97	3	601	080610	601	28.00
12/12/97	3	601	080610	601	18.00
10/03/97	3	601	080610	601	32.00
11/21/97	3	601	080610	601	10.00
04/03/98	3	601	080610	601	15.00
10/24/97	3	601	080610	601	15.00
10/10/97	3	601	080610	601	24.00
11/28/97	3	601	080610	601	12.00
03/27/98	3	601	080610	601	8.00
02/06/98	3	601	080610	601	6.00
03/20/98	3	601	080610	601	20.00
10/31/97	3	601	080610	601	10.00
03/06/98	3	601	080610	601	32.00
01/30/98	3	601	080610	601	15.00
02/27/98	3	601	080610	601	20.00
12/05/97	3	601	080610	601	18.00
10/17/97	3	601	080610	601	20.00
12/19/97	3	601	080610	601	4.00
* Subsubtotal *					529.00
* Dept Worked 602					
12/12/97	242	602	080610	602	0.50
05/08/98	242	602	080610	602	5.50
02/27/98	42	602	080610	602	2.00
* Subsubtotal *					8.00
* Dept Worked 603					
09/26/97	89	603	080610	603	8.00
09/19/97	51	603	080610	603	2.00

TABLE 3.1

LABOR FOR WORK ORDER 080310

Page No. 2 Monthly Jobcard Summary
05/27/98

Week of	Clock No.	Home Dept	Work Order No.	Dept Worked On	Hours
10/03/97	51	603	080610	603	40.00
01/30/98	51	603	080610	603	4.00
10/10/97	89	603	080610	603	3.00
11/21/97	51	603	080610	603	2.00
04/17/98	51	603	080610	603	12.00
10/24/97	51	603	080610	603	17.00
03/27/98	51	603	080610	603	38.00
02/20/98	51	603	080610	603	16.00
04/10/98	51	603	080610	603	16.00
10/17/97	51	603	080610	603	37.00
03/20/98	51	603	080610	603	6.00
04/24/98	51	603	080610	603	2.00
10/10/97	51	603	080610	603	39.00
04/03/98	89	603	080610	603	6.00
03/27/98	89	603	080610	603	20.00
02/27/98	51	603	080610	603	9.00
04/03/98	51	603	080610	603	23.00
10/17/97	89	603	080610	603	2.50
09/26/97	51	603	080610	603	28.00
03/06/98	51	603	080610	603	15.00
04/10/98	89	603	080610	603	7.00
03/13/98	51	603	080610	603	12.00
04/17/98	89	603	080610	603	11.00
08/08/97	51	603	080610	603	27.00
08/22/97	51	603	080610	603	39.00
04/24/98	89	603	080610	603	2.00
08/29/97	51	603	080610	603	24.50
05/08/98	51	603	080610	603	36.00
05/22/98	51	603	080610	603	36.00
05/08/98	89	603	080610	603	30.00
08/15/97	51	603	080610	603	31.50
05/15/98	51	603	080610	603	12.00
08/08/97	89	603	080610	603	24.00
08/15/97	89	603	080610	603	2.50
05/22/98	89	603	080610	603	25.50
01/23/98	51	603	080610	603	2.50
* Subsubtotal *					668.00
** Subtotal **					1205.00
*** Total ***					1205.00

TABLE 3-1 Continued

LABOR FOR WORK ORDER 080310

Page No 1 Monthly Jobcard Summary
05/22/98

Week of	Clock No.	Home Dept	Work Order No.	Dept Worked On	Hours
** Work Order			080610		
* Dept Worked 506					
05/08/98	190		080610	506	2.00
05/15/98	190		080610	506	1.00
05/22/98	190		080610	506	4.00
* Subsubtotal *					7.00
** Subtotal **					7.00
*** Total ***					7.00

TABLE 3-1 Continued

LABOR FOR WORK ORDER 080310

UNCLASSIFIED

APC REPORT NUMBER *0910-1093* *14 May 1998*

FINAL TECHNICAL REPORT

ANTENNA PRODUCTS

VHF-UHF FIXED STATION MAST MOUNTED ANTENNAS SYSTEM

PREPARED FOR:
U.S. ARMY CECOM ACQUISITON CENTER
FT. MONMOUTH, NJ
CONTRACT NO. DAAB07-97-C-D609

ANTENNA PRODUCTS
101 S.E. 25TH AVE.
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PHONE: 940/325-3301 * FAX: 940/325-0716

CECOM Acquisition Center
Ft. Monmouth, NJ

Contract: DAAB07-97-C-D609
May 14, 1998
Final Technical Report

VHF-UHF FIXED STATION MASTS MOUNTED ANTENNA SYSTEM

By

ANTENNA PRODUCTS CORPORATION
Mineral Wells, Texas

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Abstract

The purpose of this program is to design, build, test and deliver a VHF-UHF fixed station mast mounted antenna system. Antenna Products proposed three configurations to investigate in an effort to achieve an acceptable system.

Configuration A consisted of combining a VHF monopole/counterpoise antenna and a UHF collinear antenna. During the investigation it was found that the counterpoise did not properly terminate the radiating structure when the radials are less than a quarter wavelength long. The performance is characterized by a loss of gain at the lower frequencies. A full size structure would be larger and heavier than a dipole antenna. Therefore, no further investigation of configuration was undertaken.

Configuration B consists of combining a VHF vertical half-rhombic antenna system and a UHF collinear antenna. The rhombic antenna system was envisioned as two rhombic curtains mounted orthogonally about a 10 meter mast and would serve as guys for the mast. The UHF antenna would mount on top of the mast. It has been determined that to achieve reasonably omnidirectional azimuth patterns it is necessary to use four rhombic curtains in an azimuth array. At the interim report, the height of the antenna was 10 meters and the radius was 25 meters. Further investigations have lead to a 10 meter tall structure with 10 meter radius that uses six equally spaced slant wires that are fed in-phase near ground and connected at the top of the tower. A UHF collinear dipole array mounts on top of the dielectric mast. A prototype of this antenna is available for shipment to CECOM for further evaluation.

The propagation mode for this antenna is surfacewave instead of spacewave as commonly experienced when two antennas are mounted on masts above the earth's surface. Therefore, field tests should be conducted to determine the suitability of the antenna for the application.

Configuration C consisted of incorporating a UHF monopole/counterpoise antenna into a VHF monopole/counterpoise. Following the investigation of configuration A, the configuration was changed to dipole radiators and the monopole/counterpoises were eliminated.

Although initial efforts were encouraging, internal resonances haunted the matching of a structure within a structure approach. In view of this, the approach was changed once again to a structure around a structure much like the SB-201 in which UHF dipoles are mounted around ships masts and yet provide omnidirectional azimuthal patterns. Unfortunately, time and funds expired before these efforts could be completed.

Summary

An investigation has been conducted in an effort to design, build, test and deliver a VHF-UHF fixed station, mast mounted antenna system. Three configurations were initially considered in hopes of achieving an acceptable system.

A configuration has evolved which may possess the desired characteristics. It is described in Section 2 of this report and has been referred to as Configuration B in the interim report. It consists of a UHF collinear antenna which mounts on top of a 10 meter dielectric mast. The VHF antenna is an array of six sloping wires that connect between the top of the mast and ground at a radius of 10 meters from the mast. The wires are equally spaced in azimuth and are all fed in-phase.

The input impedance of the array is very stable and has a VSWR of less than 2:1. The radiation patterns show good gain and good azimuthal patterns, particularly at the lower frequencies. There is azimuthal variation at the higher frequencies; however, this may not be a problem due to the higher antenna gain.

Propagation at VHF frequencies near the surface of the earth occurs in a groundwave signal that is composed of a spacewave component and a surfacewave component. Normally when two dipoles are mounted above ground and separated some 20 or 30 miles, the predominate propagation modes is the spacewave component. However, in this case using the vertical half-rhombic antennas, the predominant propagation mode is the surfacewave component. As a first priority, the range of the surfacewave propagation mode should be determined. Probably the most expedient way to do this is to conduct field tests. This can be accomplished by fabricating a few antennas and using them with radios over a suitable range of paths.

Earlier a configuration (configuration A) involving counterpoise radials was investigated. Efforts were discontinued when it was discovered that the radials had to be a quarter wavelength long at the lowest frequency.

A third configuration was analyzed which consisted of an antenna in an antenna. Initially it used counterpoise radials but was changed to dipoles when the results of Configuration A became known. This antenna appeared to have potential; however, it seems to be plagued with resonances when the matching circuits are included. Therefore, it was changed once again to UHF dipoles around a VHF dipole much like the Navy uses on ships. Unfortunately, time and money expired before this approach could be fully investigated. A description of the effort to date is given in Section 3.

1.0 INTRODUCTION

The following technical report has been conducted under contract DAAB07-97-C-D609 US Army CECOM Acquisition Center, Ft. Monmouth, NJ for services, supplies, facilities and materials for approximately 5 months to design, build, test, and deliver VHF-UHF fixed station mast mounted antenna system in accordance with Antenna Products' technical proposal. Antenna Products proposed three configurations to investigate in an effort to achieve an acceptable system. All three approaches have been explored simultaneously with varying degrees of success.

Configuration B has been completed. It is presently erected at Antenna Products' test site. After inspection by CECOM representatives, the antenna will be shipped to CECOM for further evaluation.

Configuration A was discontinued at the time of the interim report.

Configuration C has been changed twice in an effort to achieve a workable system. The effort required to complete is more than was envisioned, particularly after changing directions twice. It is recommended that the present effort be continued under a new program.

Configuration B consists of combining a VHF vertical half rhombic antenna system and a UHF collinear antenna. This configuration is discussed in section 2. Configuration C became a combination of dipole antennas. This approach is given in section 3. The conclusions of the investigations to date are provided in section 4 followed by recommendations in section 5.

2.0 CONFIGURATION B

2.1 Background

The initial concept for configuration B was to have two vertical half-rhombics oriented orthogonally in space about a central mast and fed 90 degrees out of phase to provide a vertically polarized VHF antenna. The UHF antenna is a collinear array of two vertically polarized dipoles that mount on top of the mast.

As reported in the interim report the vertical half-rhombics as mentioned above produced azimuthal patterns with large variations in amplitudes. Several structures were analyzed including rhombics being fed both in phase and at some judicious selection of phases. At the time of the interim report, the best performance was obtained using four vertical half-rhombics fed in phase with the ends of the rhombics falling on a circle with radii between 20 and 25 meters. The height of the mast was maintained at 10 meters.

Since that time efforts continued with a goal to provide better azimuthal patterns along with a more realistic structure. After several analyses, it was decided to try feeding both ends of the rhombic wires instead of just one end. In effect the structure became an array of several slant wires fed in phase near ground at the outer radius of the structure. At first the mast wires were connected to the opposing wire on the opposite side of the mast. That is, the north wire had continuity to the south wire at the mast but this set of wires was insulated from other wires crossing the mast near the same height. This resulted since the configuration evolved from the idea of using vertical half-rhombics. However, it was established that all wires could be connected at the top of the mast. This fact should have been evident sooner since all feed points are fed in-phase and therefore the voltage from each source is the same at the top of the mast.

Next came the matter of whether the mast had to be dielectric or could a metal mast be used. Both the radiation patterns and the impedances confirm that a dielectric mast is required.

An attempt to achieve a practical structure resulted in reducing the radius of the sloping wires to that of the tower height, namely 10 meters.

Finally, recalling the investigations on Configuration A earlier where a quarter wavelength element produced useful results when the radial counterpoise was large, it was decided to try feeding a quarter wavelength element against the apparent slant counterpoise. Should this approach work, there would be two vertical omnidirectional antennas in the one structure. The element was mounted on top of the mast. The counterpoise element appeared to work fine although extensive tests were not conducted. The problem with the structure was that the isolation between the two VHF antennas was of the order of 10 dB. However, it is worth noting that should the surface wave propagation mode of the present configuration not provide sufficient range, then the space wave component of the element being fed against a large radial counterpoise will probably work.

2.2 VHF Array

The following sections describe the VHF antenna array and provide the performance of the antenna.

2.2.1 Description

Figure 2-1 depicts the VHF antenna array. It consists of six equally spaced wires about a central mast which slope from near ground to the top of the mast. The six wires are fed in phase at their extremities near ground and are connected electrically at a height of 10 meters above ground at the central mast. The mast is dielectric.

Each of the six inputs has an impedance of 300 ohms, nominal. This impedance is transformed to 75 ohms using a 4:1 autotransformer with compensation circuits. The schematic of this transformer is shown in figure 2-2.

The six 75 ohm inputs are connected to a combiner at the base of the mast through the use of six 75 ohm coaxial cables, RG-11.

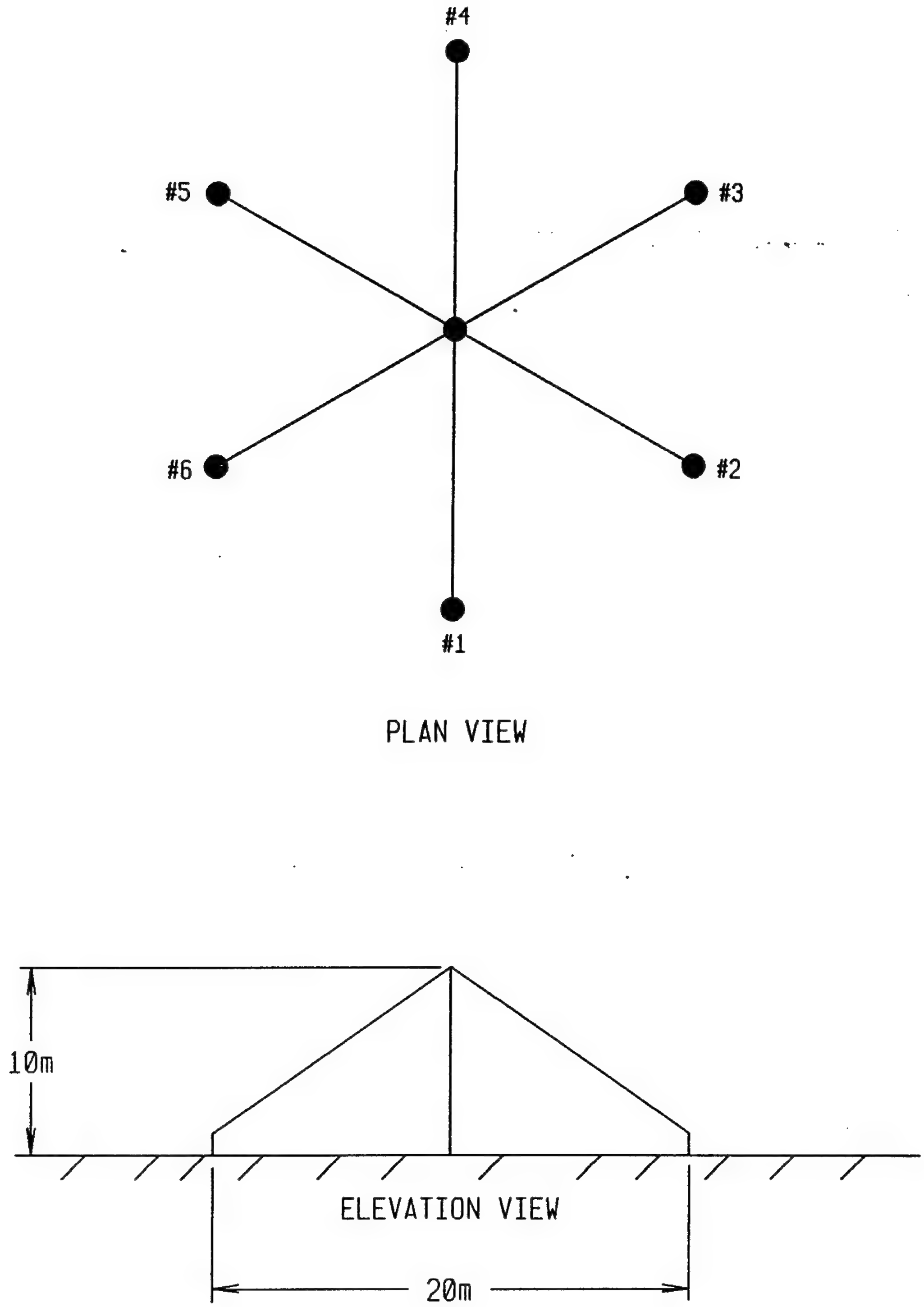


FIGURE 2-1
VHF ARRAY

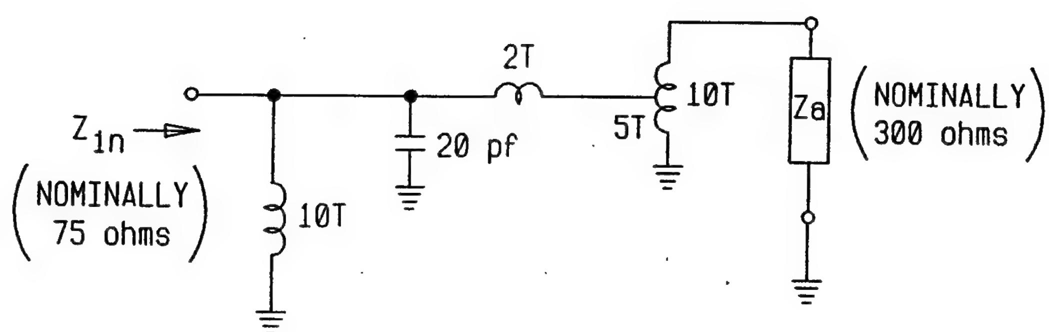


FIGURE 2-2
VHF Element Transformer and Compensation Circuit

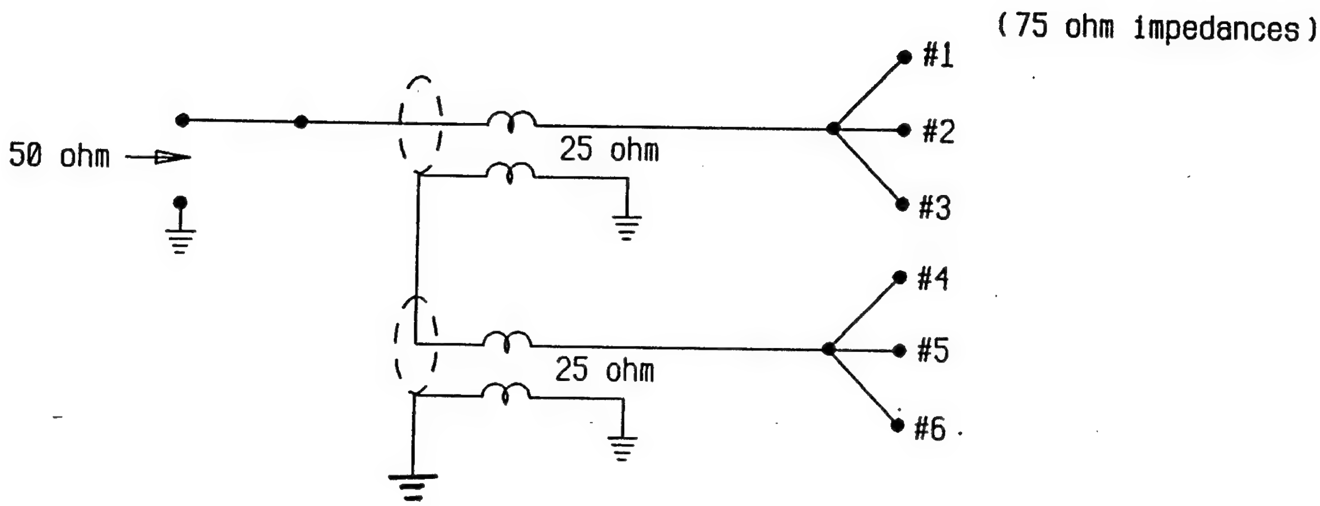


FIGURE 2-3
VHF COMBINER

The combiner is shown in figure 2-3. The desired 50 ohm input is achieved with a series arrangement of two 25 ohm impedances. Each 25 ohm impedance consists of a parallel combination of three of the 75 ohm coaxial lines feeding the element.

A picture of the antenna is shown in figure 2-4. The UHF antenna is mounted on top of the mast. The masts used for the two prototype antennas are the MAC-10/07C and the MAC-10/07P. The C version is crank up and the P version is push up. Both masts are identical except for erection methods and are telescoping composite designs. Data sheets for the two masts are provided in Appendix A.

A picture of the autotransformer used at each element feed is contained in figure 2-5 and a picture of the combiner is given in figure 2-6. No attempt has been made to design the antenna as a serviceable item. The design is an rf breadboard to show performance and verify the analyses.

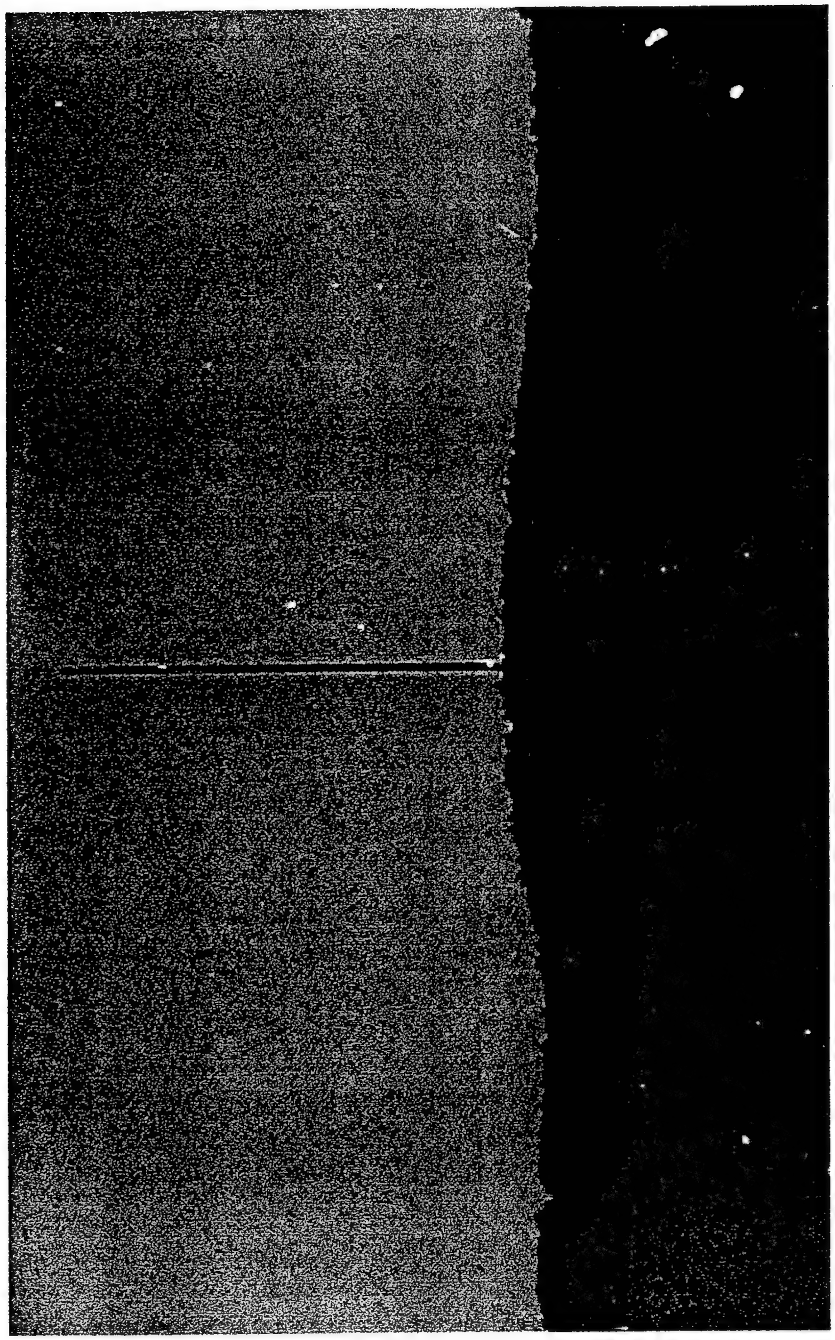


FIGURE 2-4
Configuration B Antenna Mounted On A
MAC-10/07P Composite Telescoping Mast

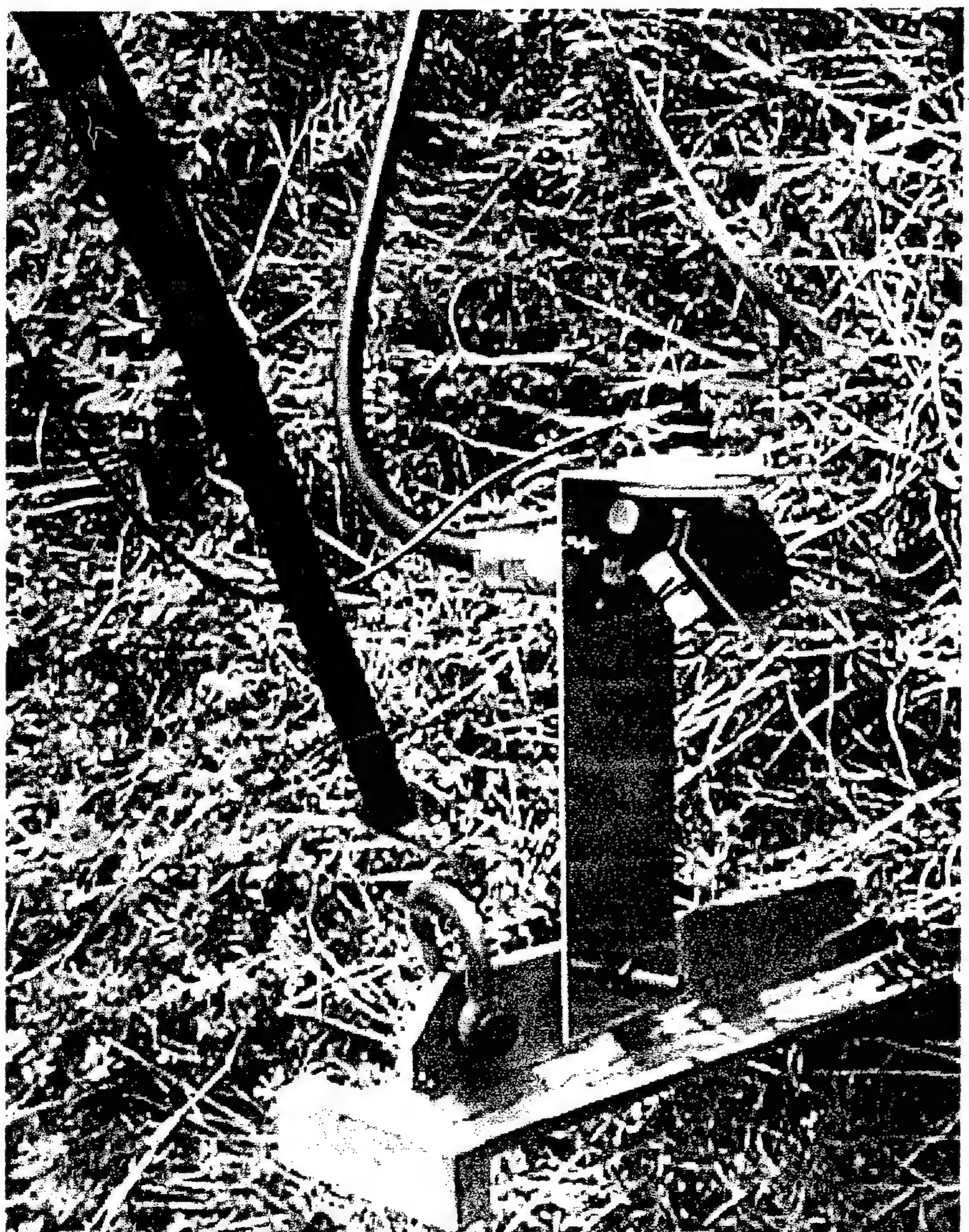


FIGURE 2-5
Element Autotransformer with Compensating Circuits

FIGURE 2-6
Picture of 6-Way Combiner Located
At Base of Antenna Mast

2.2.2 Impedances

The input impedance from each element of the array is centered about 300 ohms. In the course of the analysis the 30 to 90 MHz band was subdivided into 80 frequencies. Each plot file from NEC-3 has a maximum of 40 frequencies per run. So the frequencies were stepped geometrically and two runs were made for each configuration analyzed.

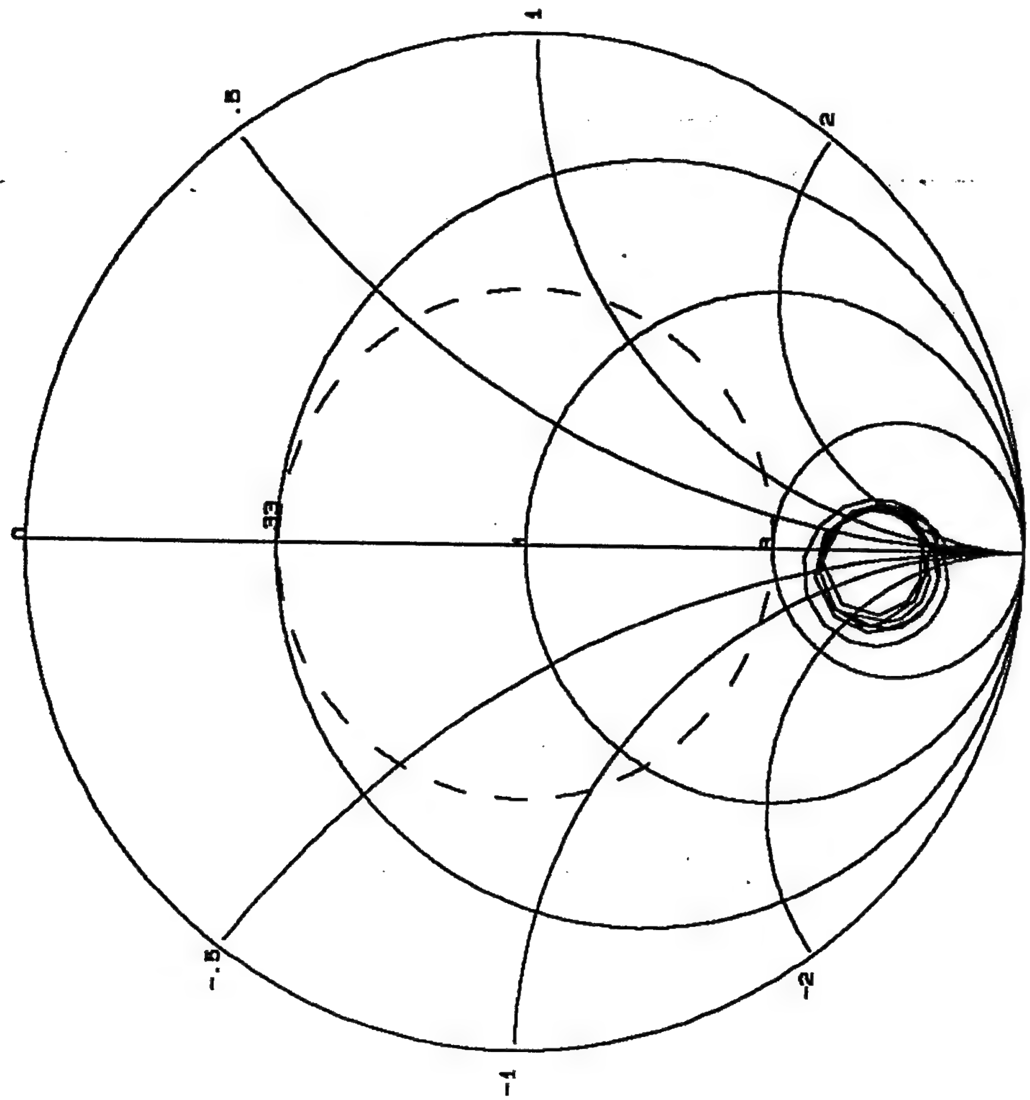
Figure 2-7 shows the impedance of the 80 frequencies covering the 30 to 90 MHz band plotted on a Smith Chart for the configuration shown in the last section. There are six elements equally spaced in a circular array with the wires being connected (shorted) at the top of the mast. As shown the computed impedances circle nicely about 300 ohms. This information was used as a design basis for the autotransformer and combiner shown earlier. Figure 2-8 shows the measured input impedance when the six element transformers, the 6 RG-11 coaxial lines and the combiner are included. The UHF collinear is mounted on top of the mast. Figure 2-9 shows the input VSWR of the VHF antenna measured at the combiner at the antenna base. An HP-8753D network analyzer was used to take this data. We used 801 frequencies in the 30 to 90 MHz band in an effort to catch any resonances in the structure.

Figure 2-10 shows the measured insertion VSWR of the combiner, coaxial cables and auto transformers when the auto transformers were terminated in 300 ohms. As can be seen the insertion VSWR is less than 1.2:1 of the transforming and combining network.

As a comparison to the input impedance of the antenna without the UHF antenna mounted on top of the mast, figures 2-11 and 2-12 show the impedance and VSWR without the UHF antenna. These should be compared to figures 2-8 and 2-9. As can be seen there are only slight differences in the impedance and VSWR with and without the UHF antenna installed.

The isolation between the VHF and UHF antennas is provided in figure 2-13. As shown, the minimum isolation is roughly 40 dB at 102 MHz and 43 dB at 90 MHz. The 43 dB at 90 MHz is the lowest in-band isolation.

Another point of interest is the use of a metal mast instead of the dielectric mast. Figure 2-14 shows the computed impedance of the antenna using a metal mast. This can be compared with the impedance shown in figure 2-7 without a mast. As shown, the metal mast disrupts the nice smooth plot of the impedance and indicates periodic reflections, which not only changes the impedance but also the patterns.



Three Rhombic Antenna Array
Six Feed Array : No Mast : L = 10 M
Impedance = 50 Ohms : 04-04-1998

FIGURE 2-7

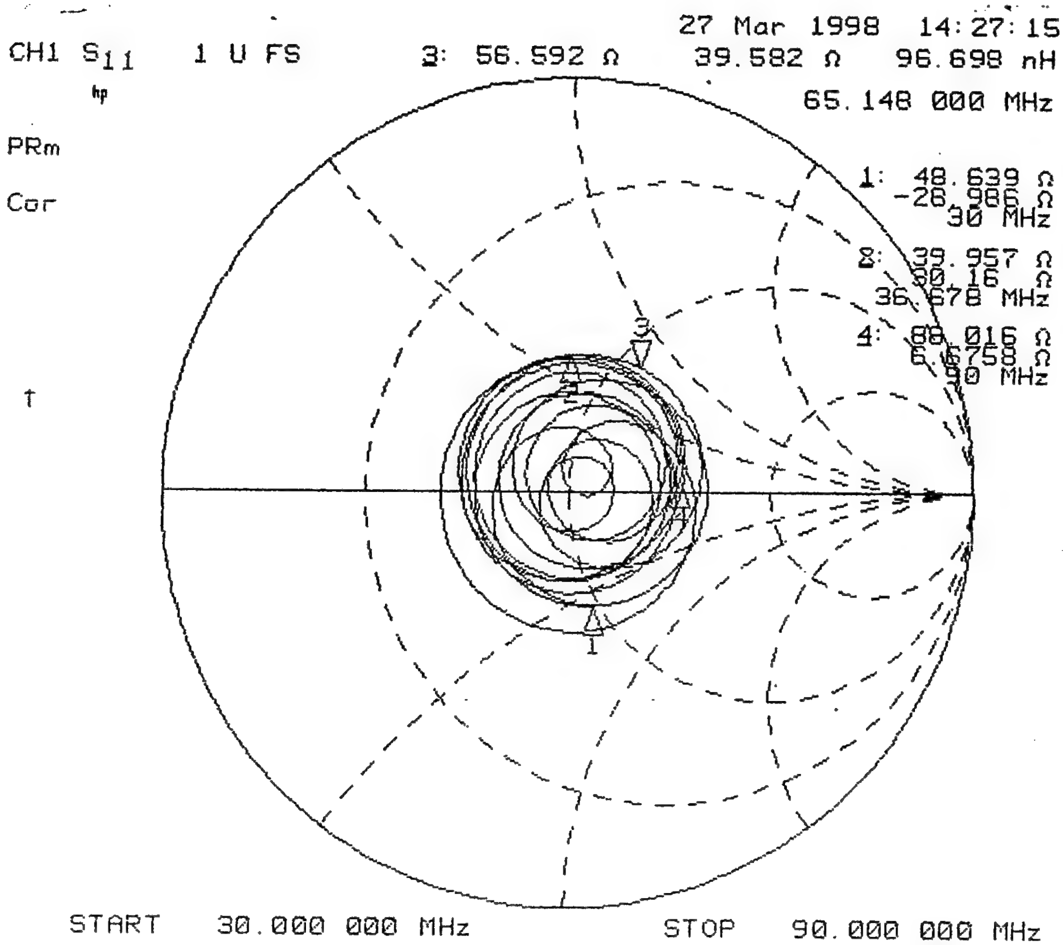


FIGURE 2-8
Input Impedance at Base of Mast

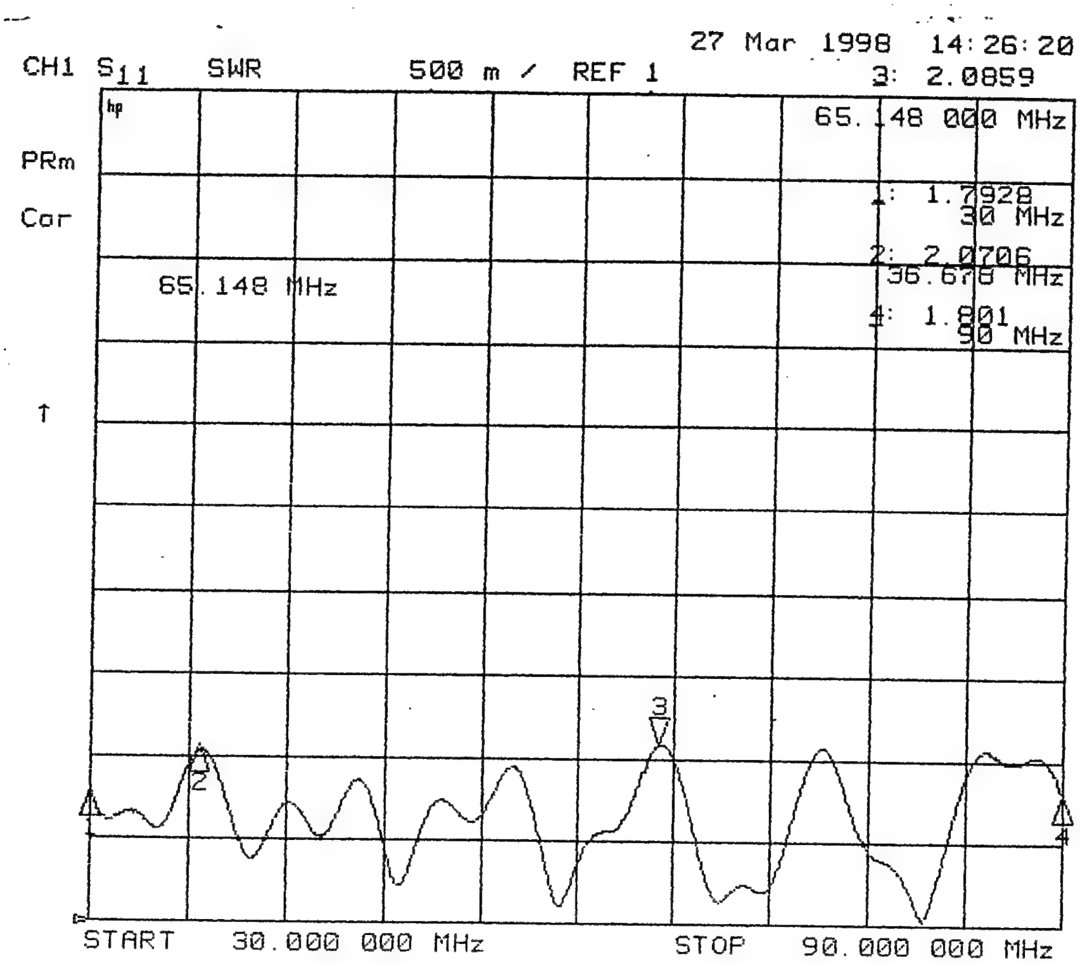


FIGURE 2-9
VSWR of VHF Antenna With collinear Mounted on Top of Mast

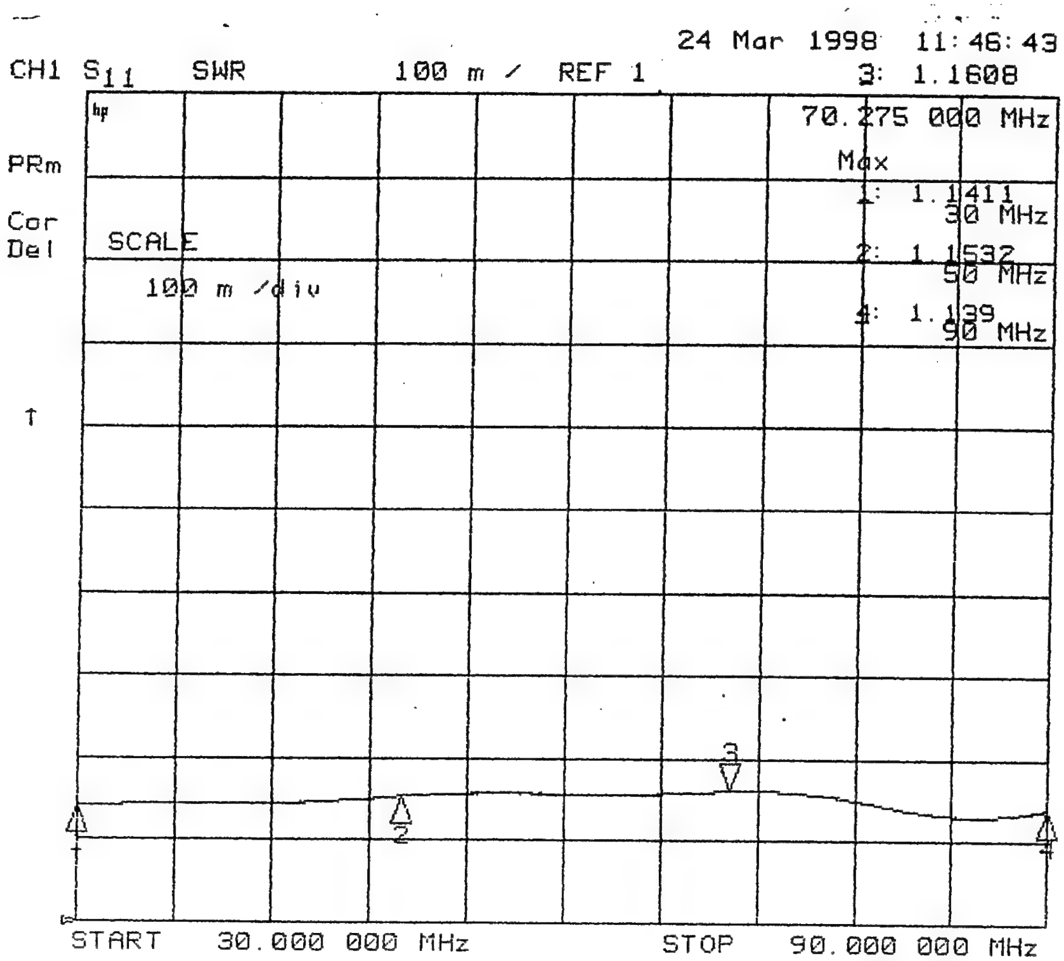


FIGURE 2-10
Insertion VSWR of the Transforming and Combining Network

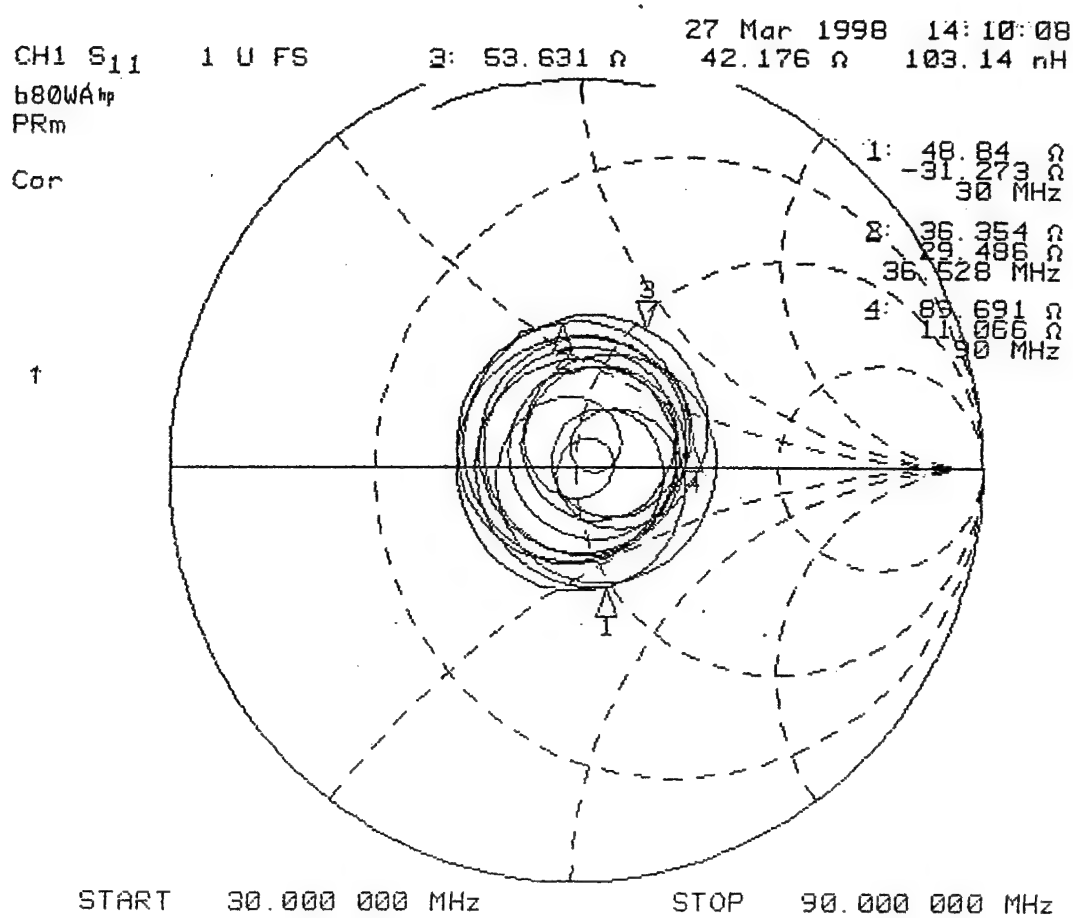


FIGURE 2-11
Impedance of VHF Antenna Without UHF Antenna

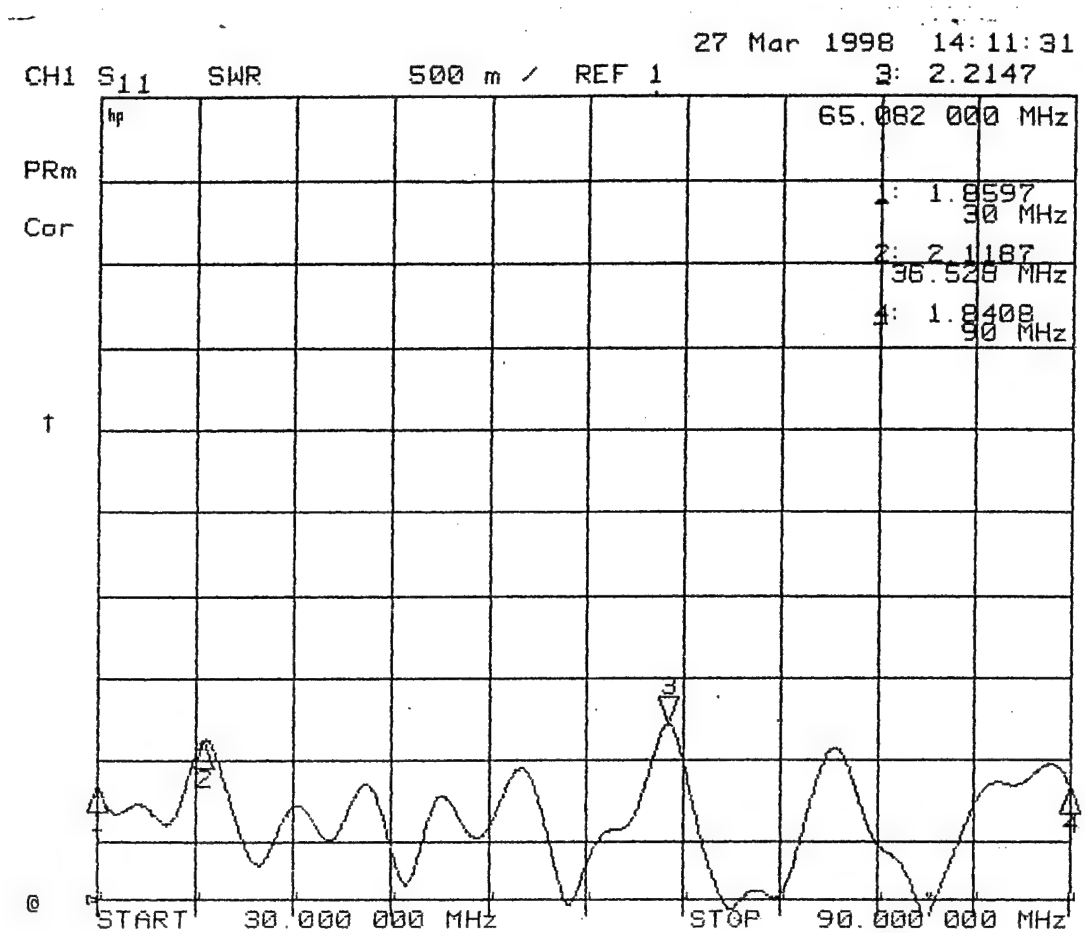


FIGURE 2-12
VSWR of VHF Antenna Without UHF Antenna

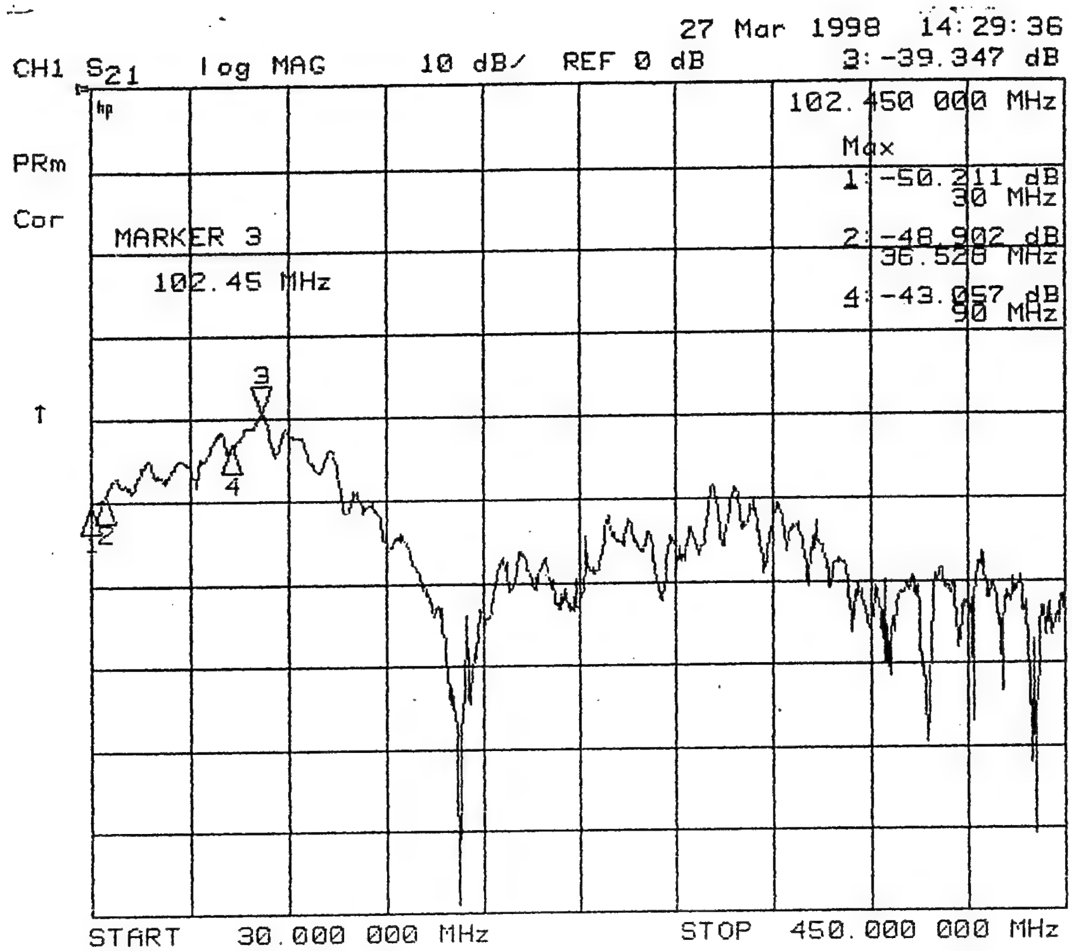
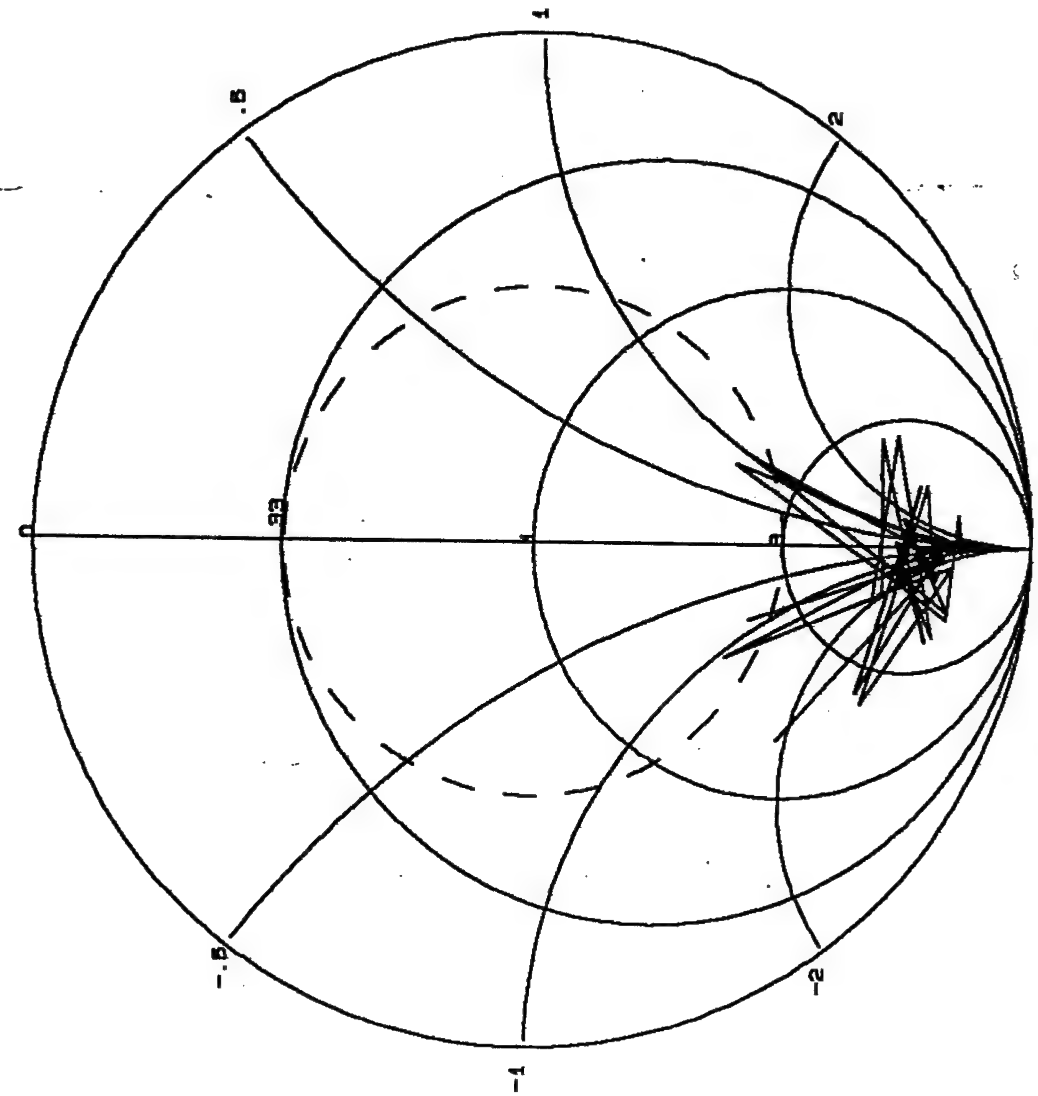


FIGURE 2-13
Isolation of VHF and UHF Antennas



Three Rhombic Antenna Array
Central Metal Mast
Impedance = 50 Ohms : 02-24-1998

FIGURE 2-14
Antenna Impedance With Metal Mast

2.2.3 Radiation Patterns

Radiation patterns were computed using NEC-3 for the antennas over perfect ground. A Sommerfeld analysis was not conducted to estimate the surface wave component versus distance. Rather, the analysis presented should provide the relative performance of the antenna and estimate the omnidirectional characteristics.

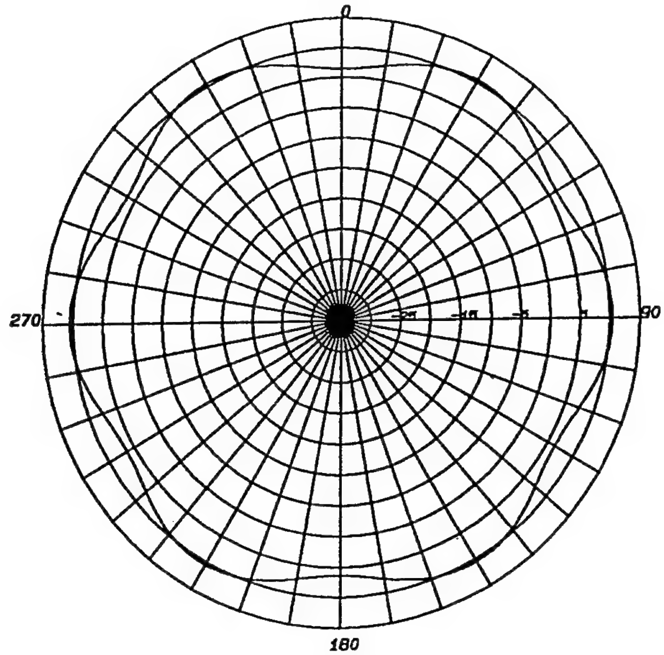
Figures 2-15 through 2-27 provide the azimuth and elevation patterns of the antenna at 5 MHz intervals through the 30 to 90 MHz band. At the lower frequencies the azimuth scallops are about + or – 2 dB. This condition degrades for some of the higher frequencies.

The elevation patterns show that the elevation lobes increase with frequency. This condition increases as the radius of the extremities of the elements increase. As can be seen from the patterns the maximum gain does not always appear at the surface of perfect earth. This, of course is expected when operation is over a 3:1 frequency band.

It is of interest to analyze the performance of the antenna when the sets of wires are insulated from each other. A set of wires means say, the north wire and the south wire, or any two wires that are separated by 180 degrees. The impedance and radiation patterns for this arrangement are shown in Appendix B. The impedances and patterns are very near those where the elements are shorted.

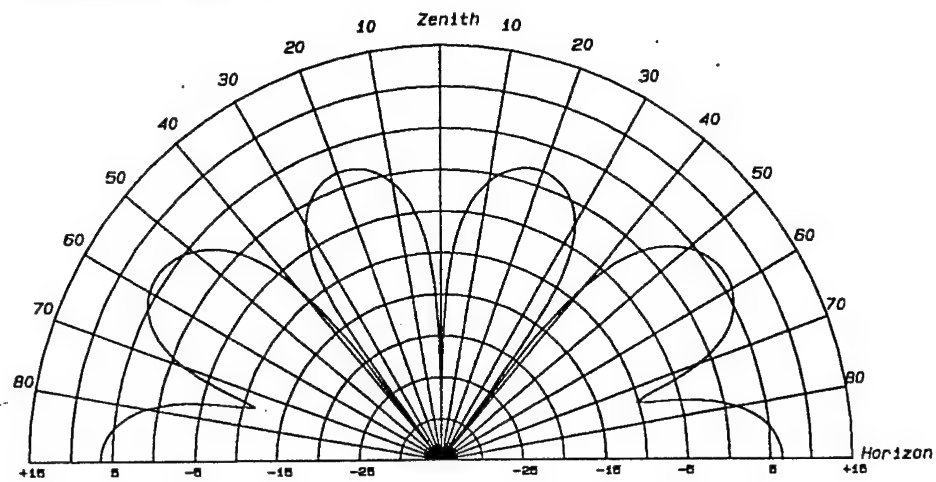
Another variation of interest was to add a metallic rod to the top of the mast where the six element wires connect. The rod was 1.5 meters which is a length near that normally taken as a quarter wavelength for this band. The results are given in Appendix C. As can be seen the impedances vary considerable from before resulting in a much higher VSWR. As far as the radiation patterns are concerned some frequencies have a smoother pattern with less variation. Other patterns have much deeper scallops. The net effect was to increase the Q of the structure as opposed to smoothing performance versus frequency.

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 30 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

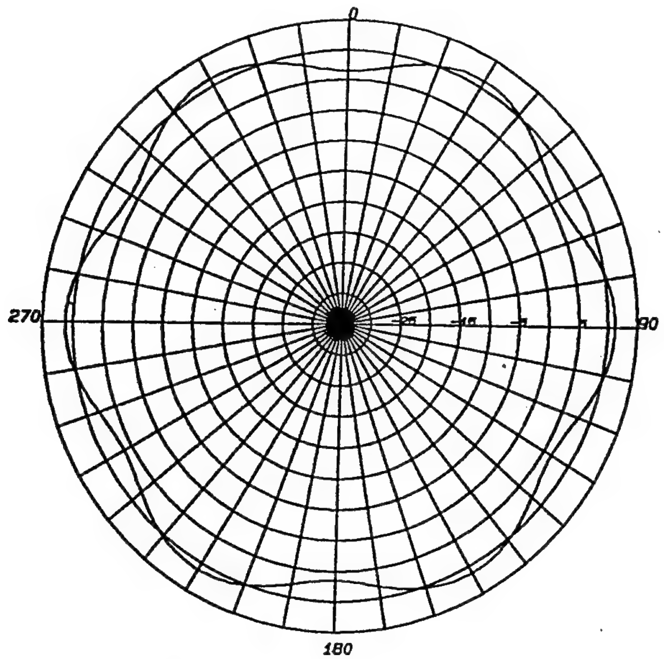
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 30 MHz : Dielectric Mast
Gain = 6.5 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

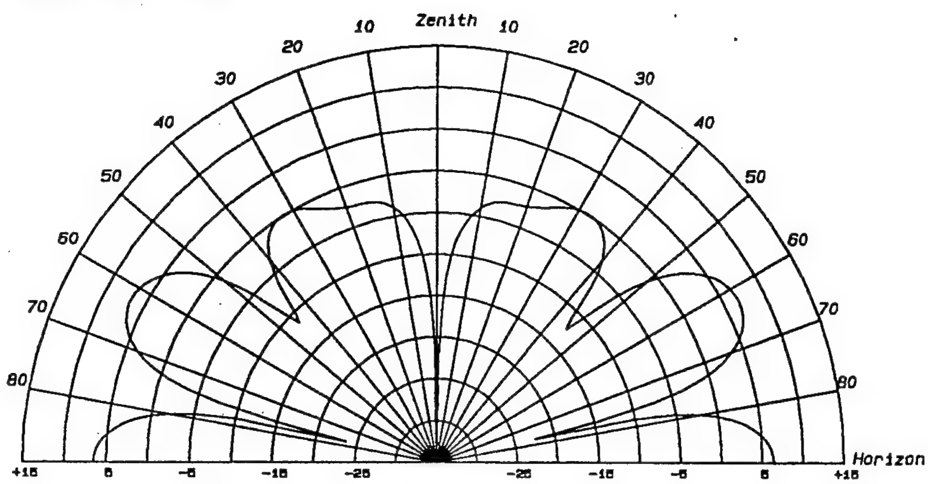
FIGURE 2-15

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 35 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

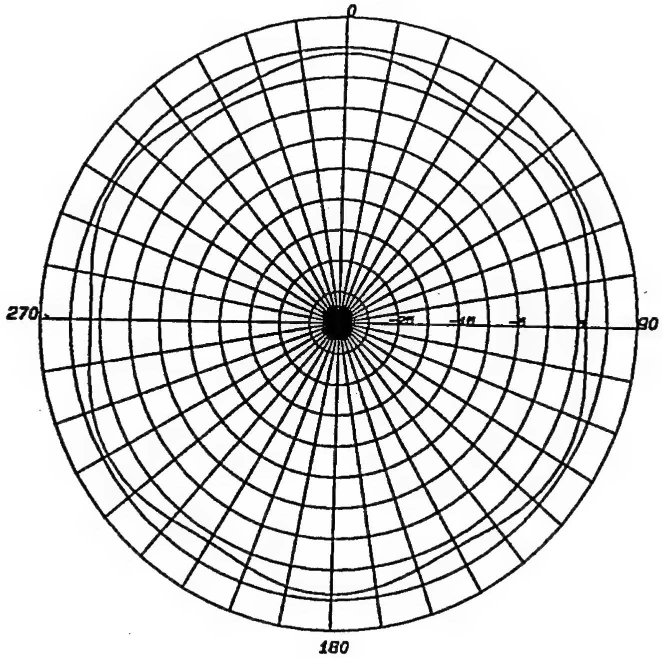
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 35 MHz : Dielectric Mast
Gain = 6.83 dBi : Theta = 62 Degrees
Perfect Ground : Leg = 10 Meters

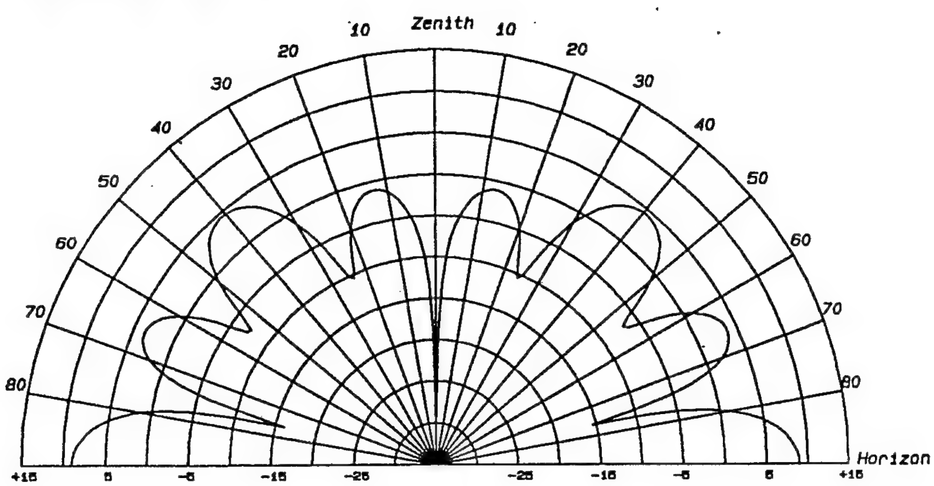
FIGURE 2-16

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 40 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

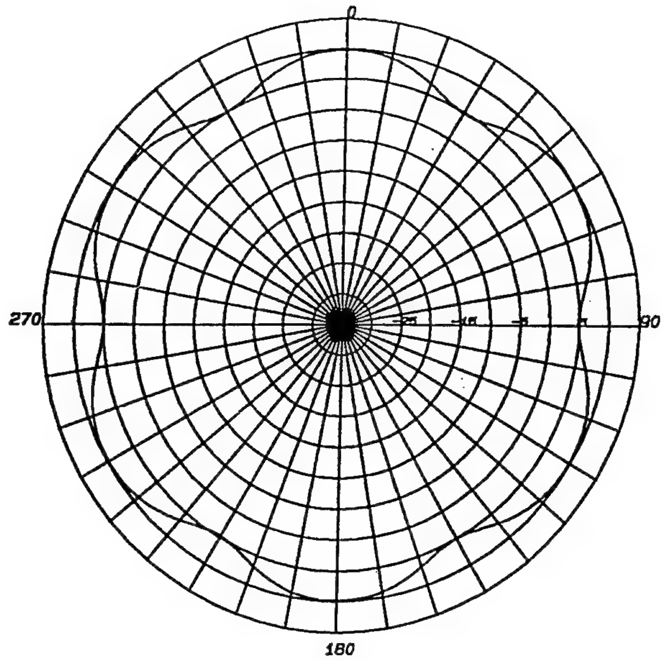
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 40 MHz : Dielectric Mast
Gain = 8.98 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

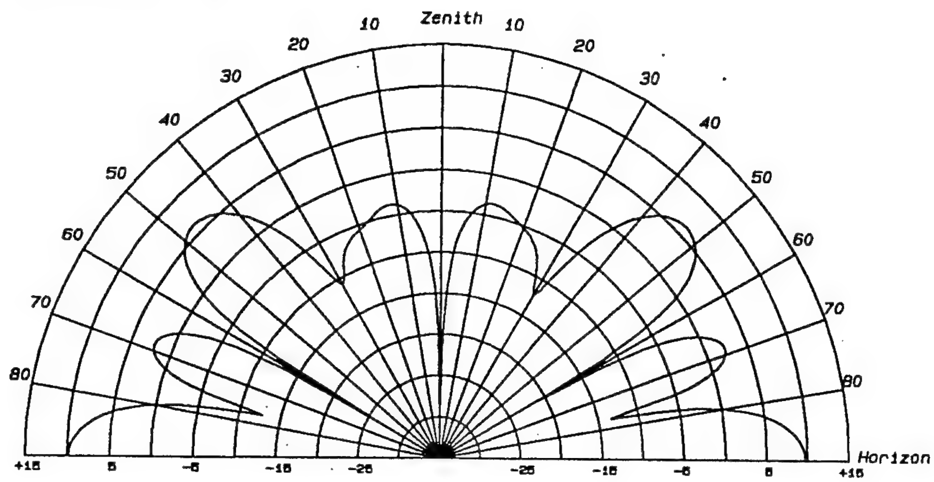
FIGURE 2-17

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 45 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

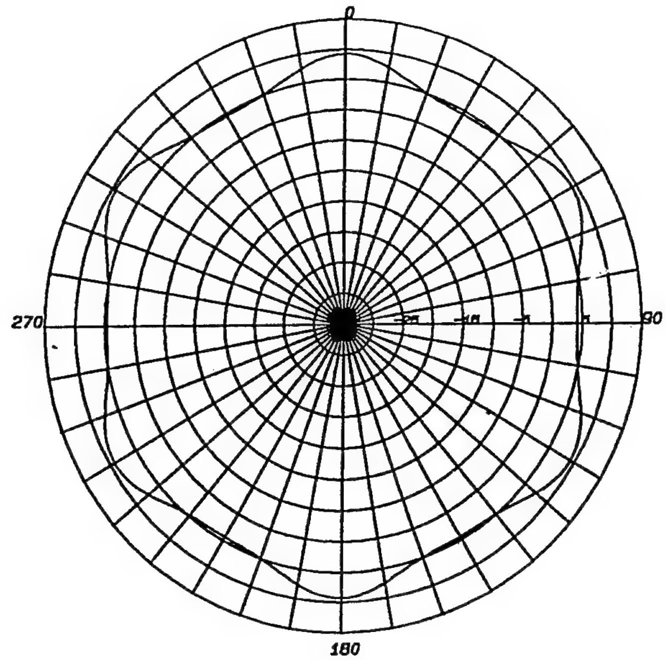
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 45 MHz : Dielectric Mast
Gain = 9.8 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

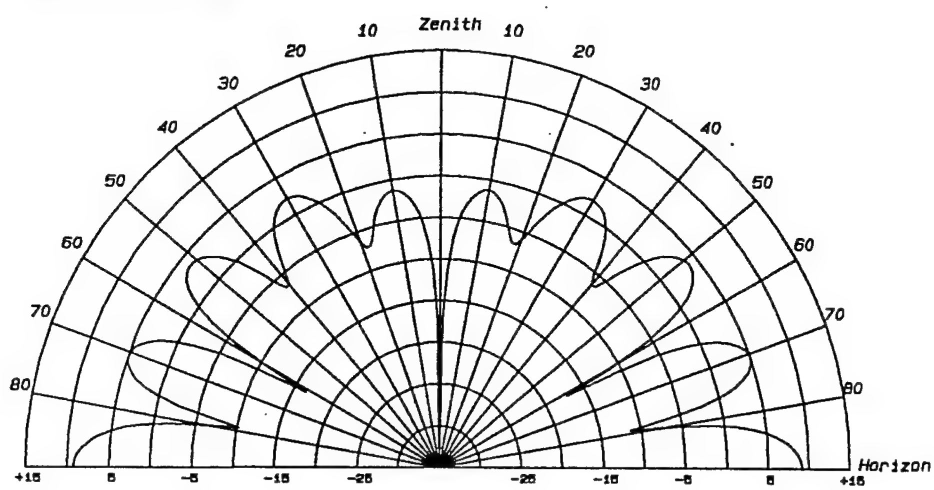
FIGURE 2-18

Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 50 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

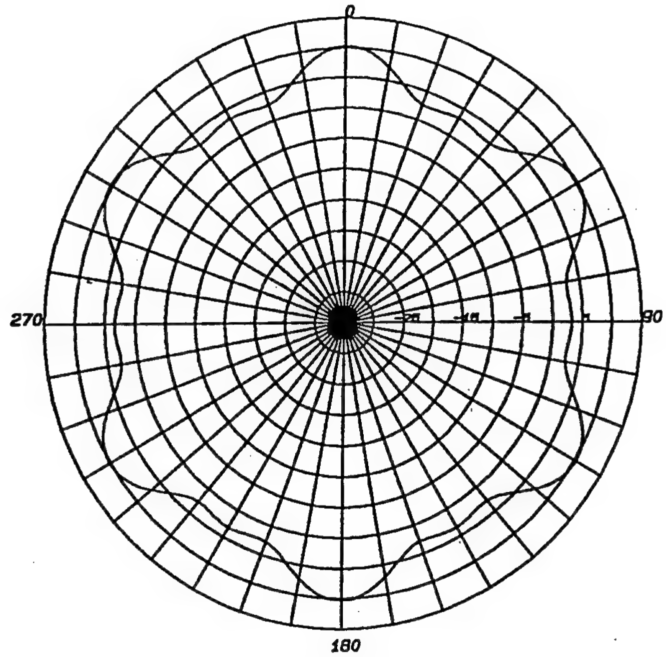
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 50 MHz : Dielectric Mast
Gain = 9.23 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

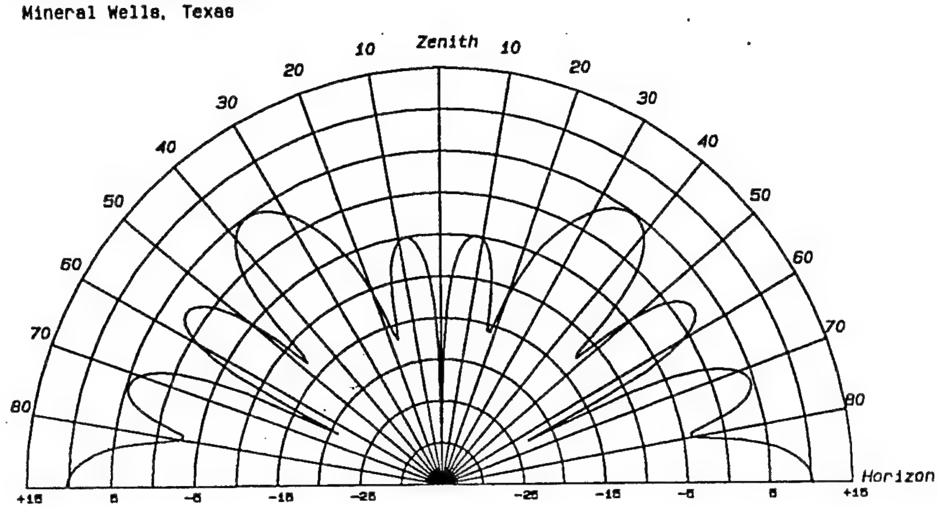
FIGURE 2-19

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 55 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

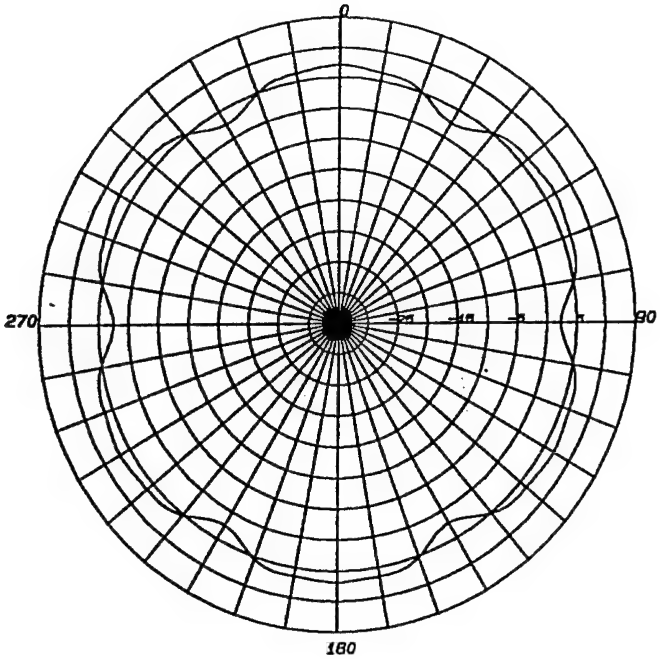
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 55 MHz : Dielectric Mast
Gain = 10.2 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

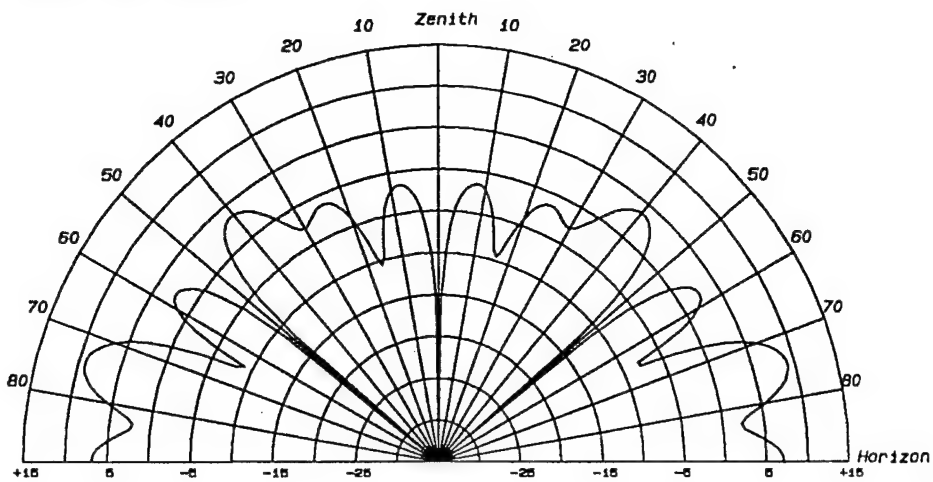
FIGURE 2-20

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 60 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

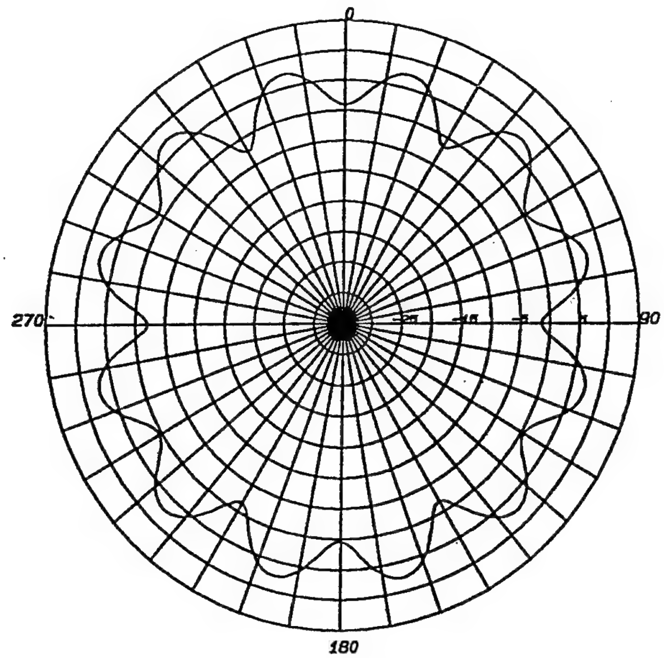
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 60 MHz : Dielectric Mast
Gain = 9.21 dBi : Theta = 75 Degrees
Perfect Ground : Leg = 10 Meters

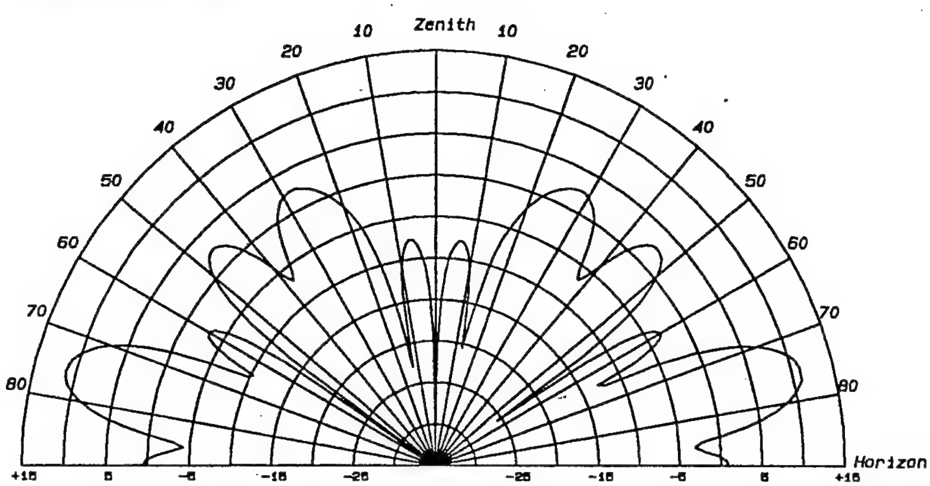
FIGURE 2-21

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 65 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

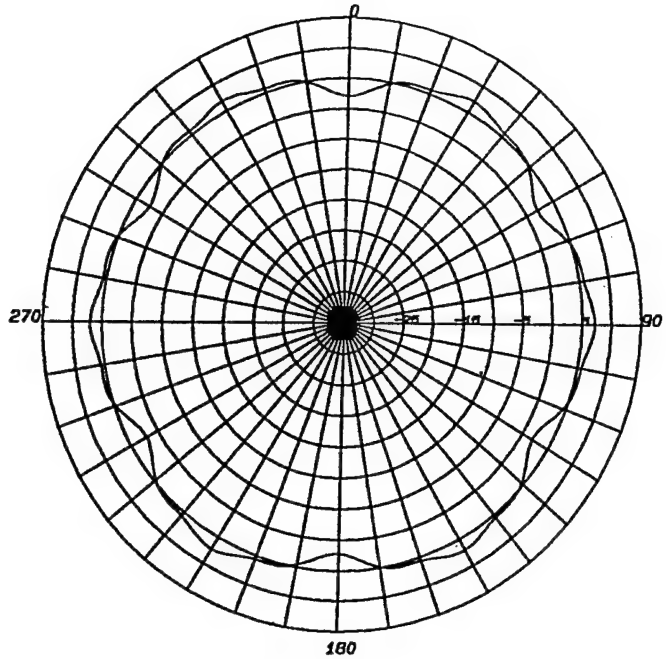
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 65 MHz : Dielectric Mast
Gain = 11.1 dBi : Theta = 76 Degrees
Perfect Ground : Leg = 10 Meters

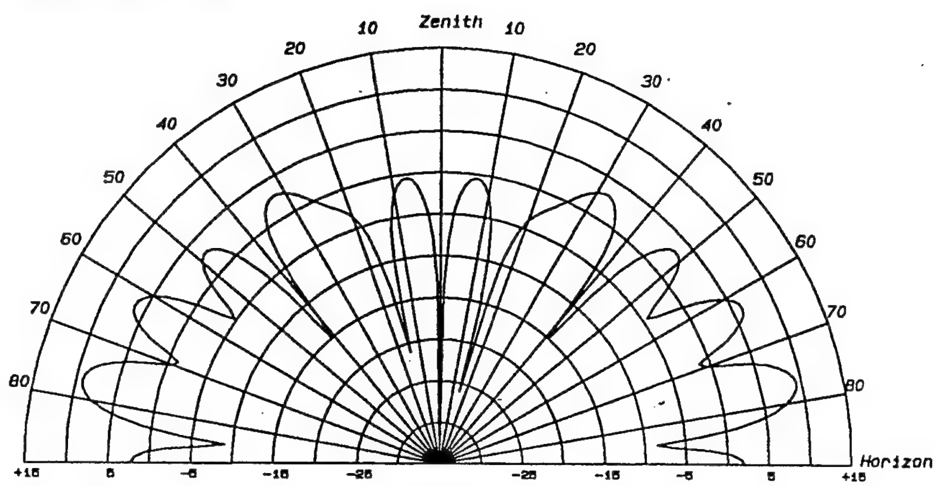
FIGURE 2-22

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 70 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

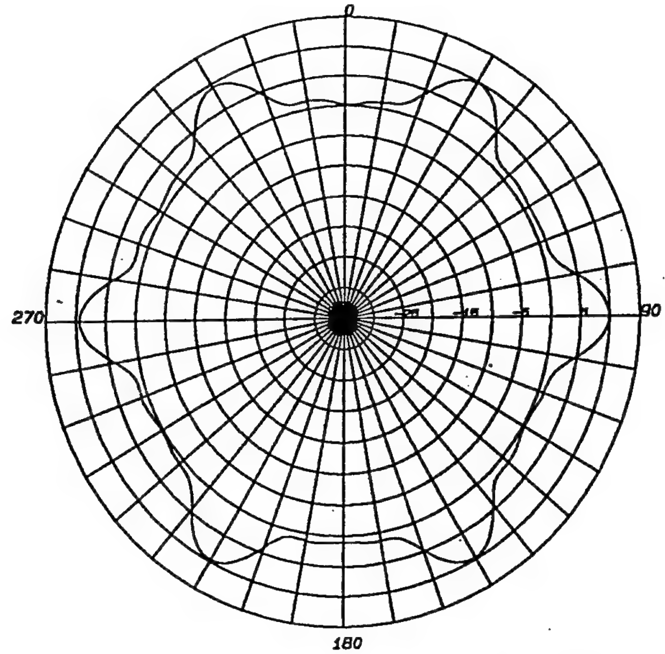
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 70 MHz : Dielectric Mast
Gain = 9.33 dBi : Theta = 77 Degrees
Perfect Ground : Leg = 10 Meters

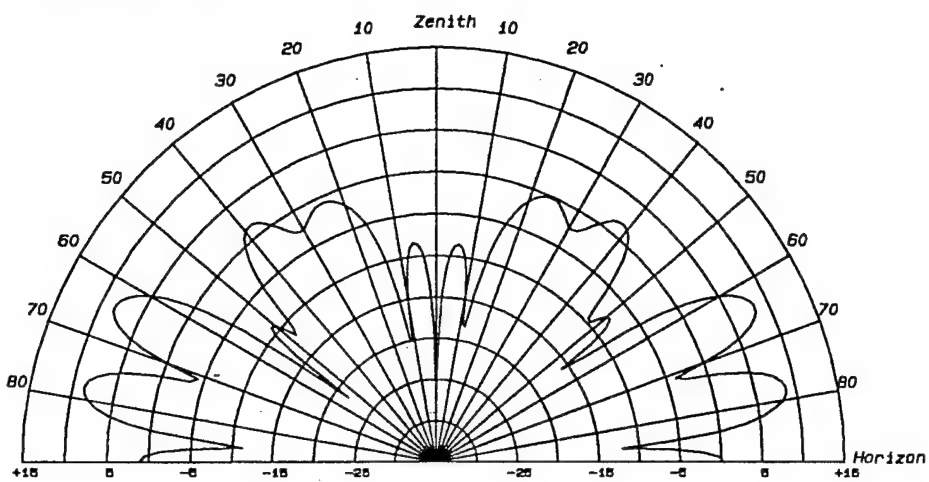
FIGURE 2-23

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 75 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

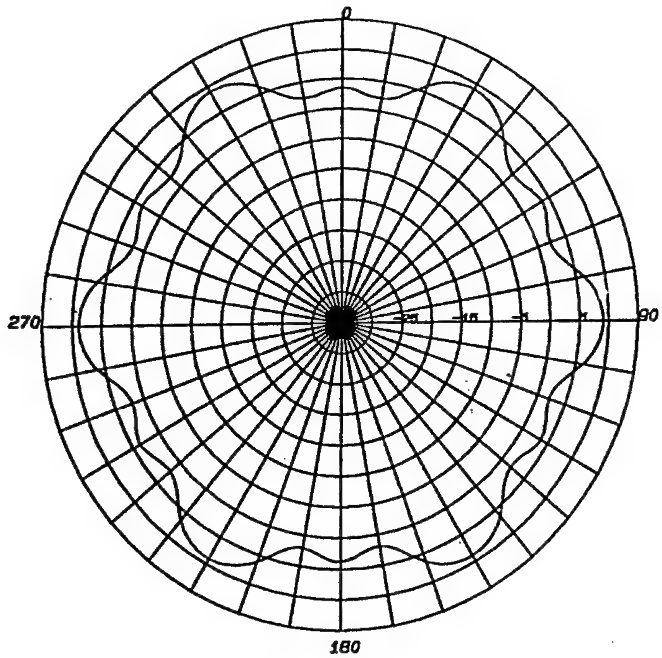
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 75 MHz : Dielectric Mast
Gain = 6.82 dBi : Theta = 78 Degrees
Perfect Ground : Leg = 10 Meters

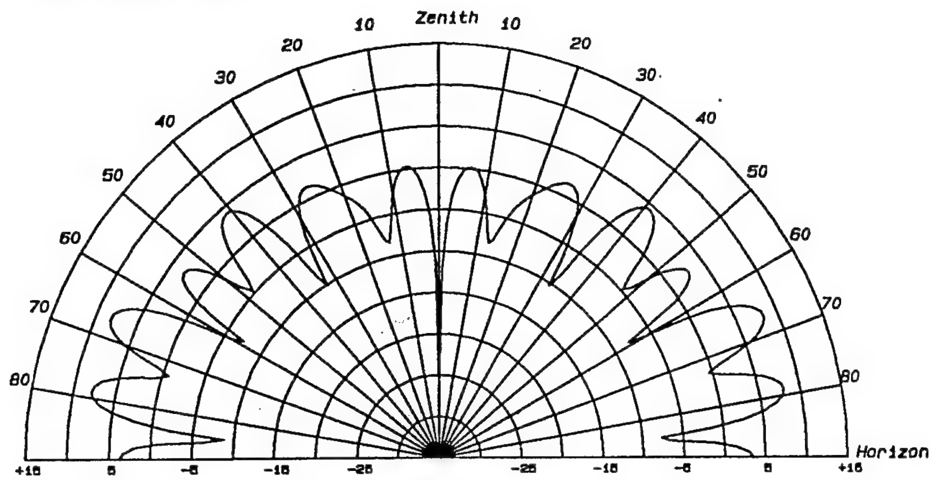
FIGURE 2-24

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 80 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

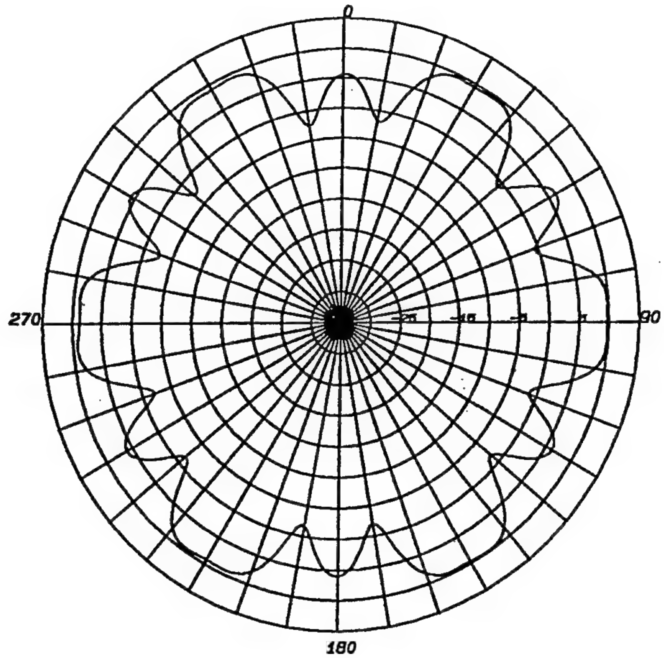
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 80 MHz : Dielectric Mast
Gain = 8.23 dBi : Theta = 67 Degrees
Perfect Ground : Leg = 10 Meters

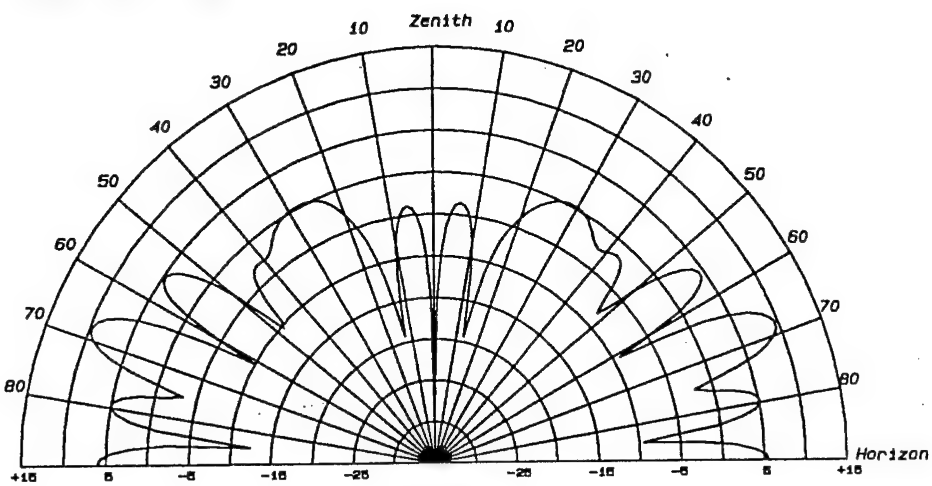
FIGURE 2-25

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 85 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

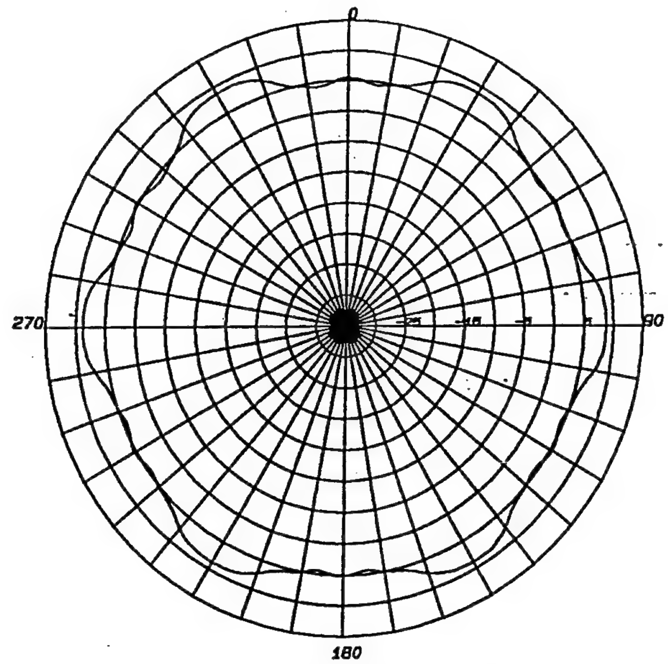
Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 85 MHz : Dielectric Mast
Gain = 9.7 dBi : Theta = 68 Degrees
Perfect Ground : Leg = 10 Meters

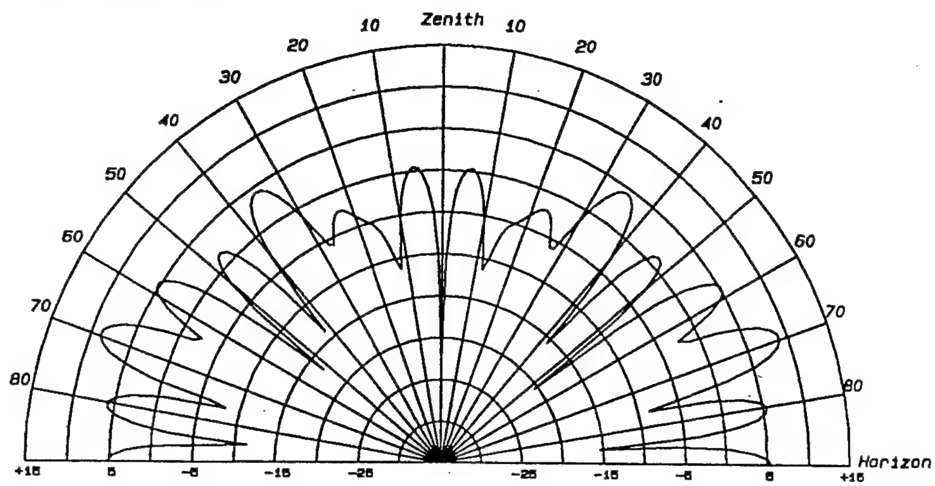
FIGURE 2-26

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 90 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 90 MHz : Dielectric Mast
Gain = 8.97 dBi : Theta = 70 Degrees
Perfect Ground : Leg = 10 Meters

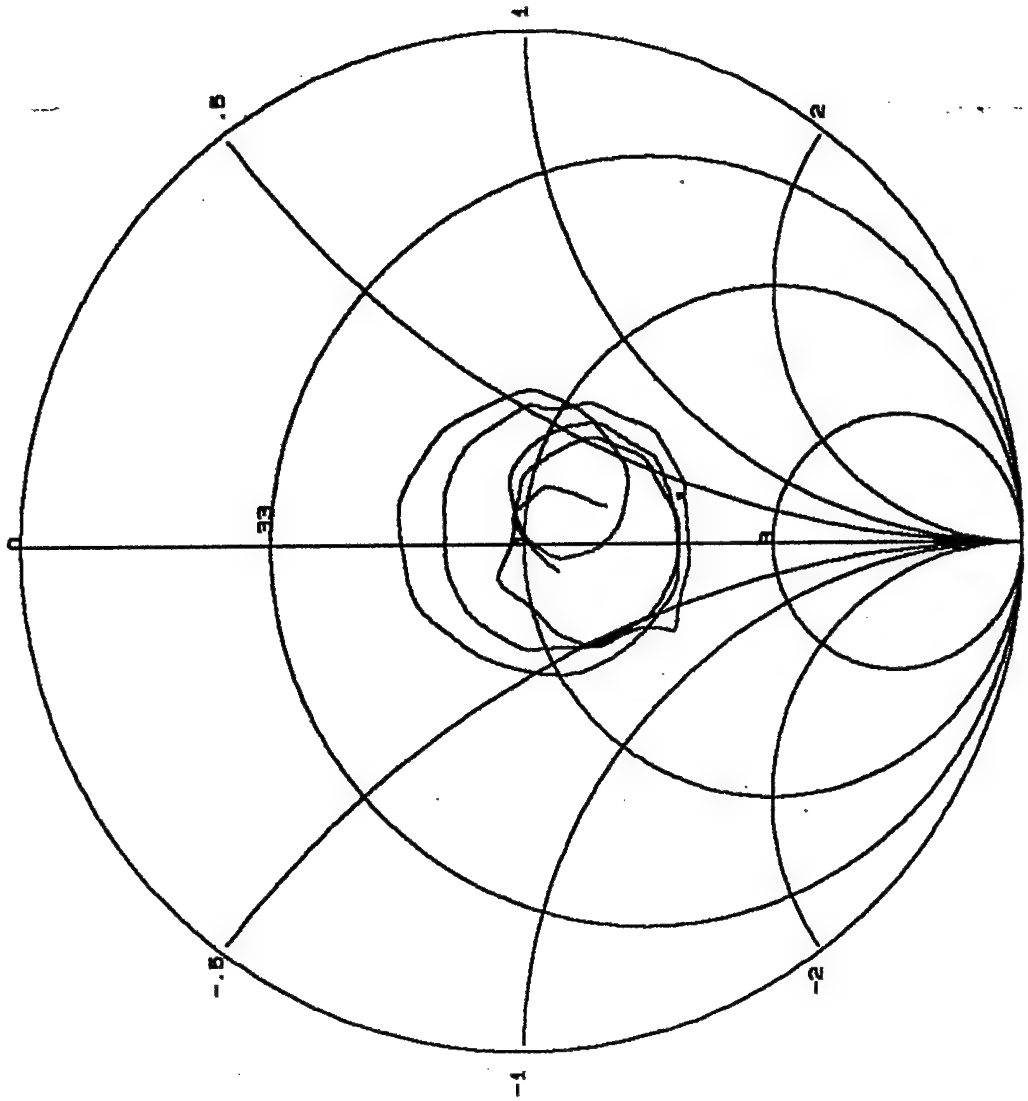
FIGURE 2-27

2.3 UHF Antenna

The UHF antenna consists of two collinear dipoles fed in phase. The antenna is a modified version of our DPV-51 antenna to operate over the frequency range of 225 to 450 MHz. The input impedance and VSWR of the antenna is shown in figures 2-28 and 2-29. The VSWR of the antenna is a maximum of 2:1 with respect to 50 ohms.

Gain measurements were made by mounting two antenna on 45 foot masts and separating the masts 20 feet. An HP-8753D network analyzer was used to measure the isolation (S12 & S21) and the gain was computed using the Friis transmission equation. A description of this technique was included in the interim report last December. Figure 2-30 provides the measured gain of the antenna as a function of frequency. The test used 801 frequencies in the 225 to 450 MHz range.

Radiation patterns were measured for the antenna in 25 MHz intervals. Due to the azimuth symmetry of the antenna, only E-plane patterns were measured. These are given in figures 2-31 through 2-40.



Measured Antenna Impedances
Z0 = 50 Ohms : 03-31-1998
DPV-51 Vertical Collinear Antenna

FIGURE 2-28

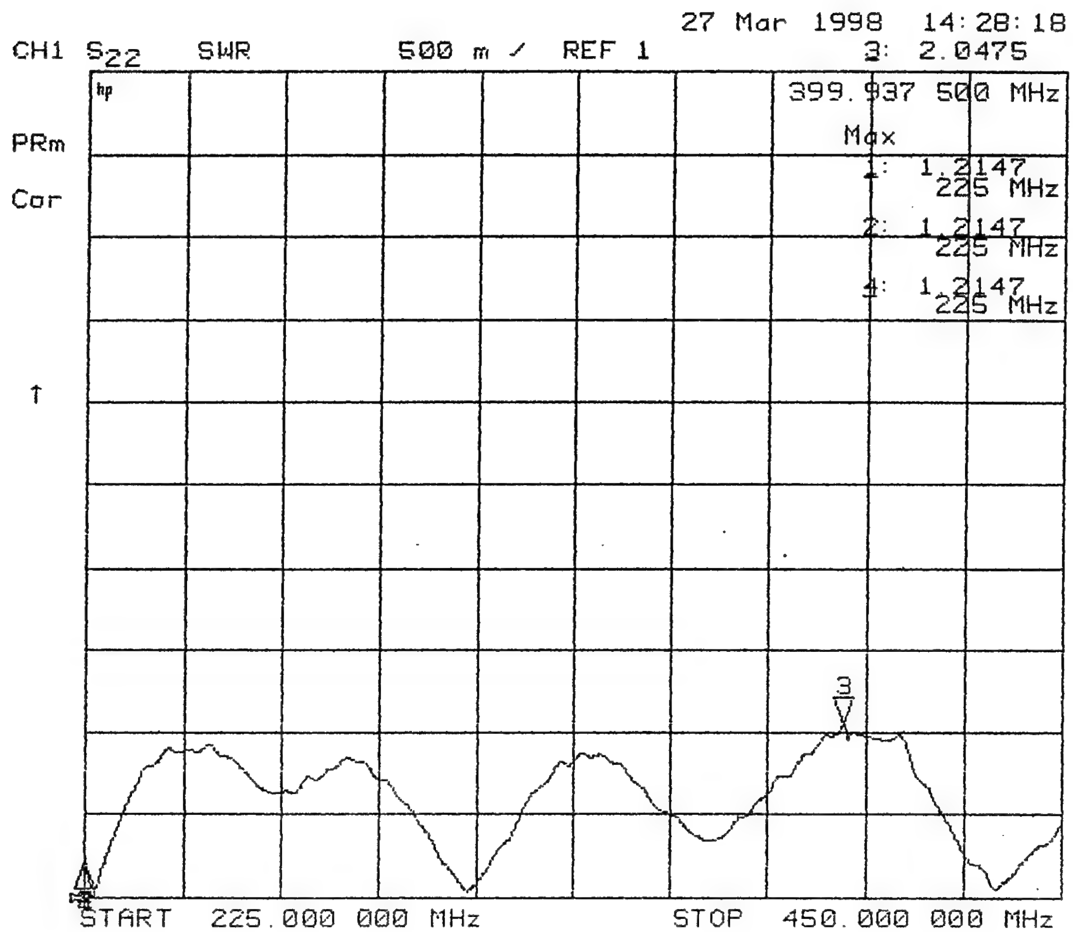
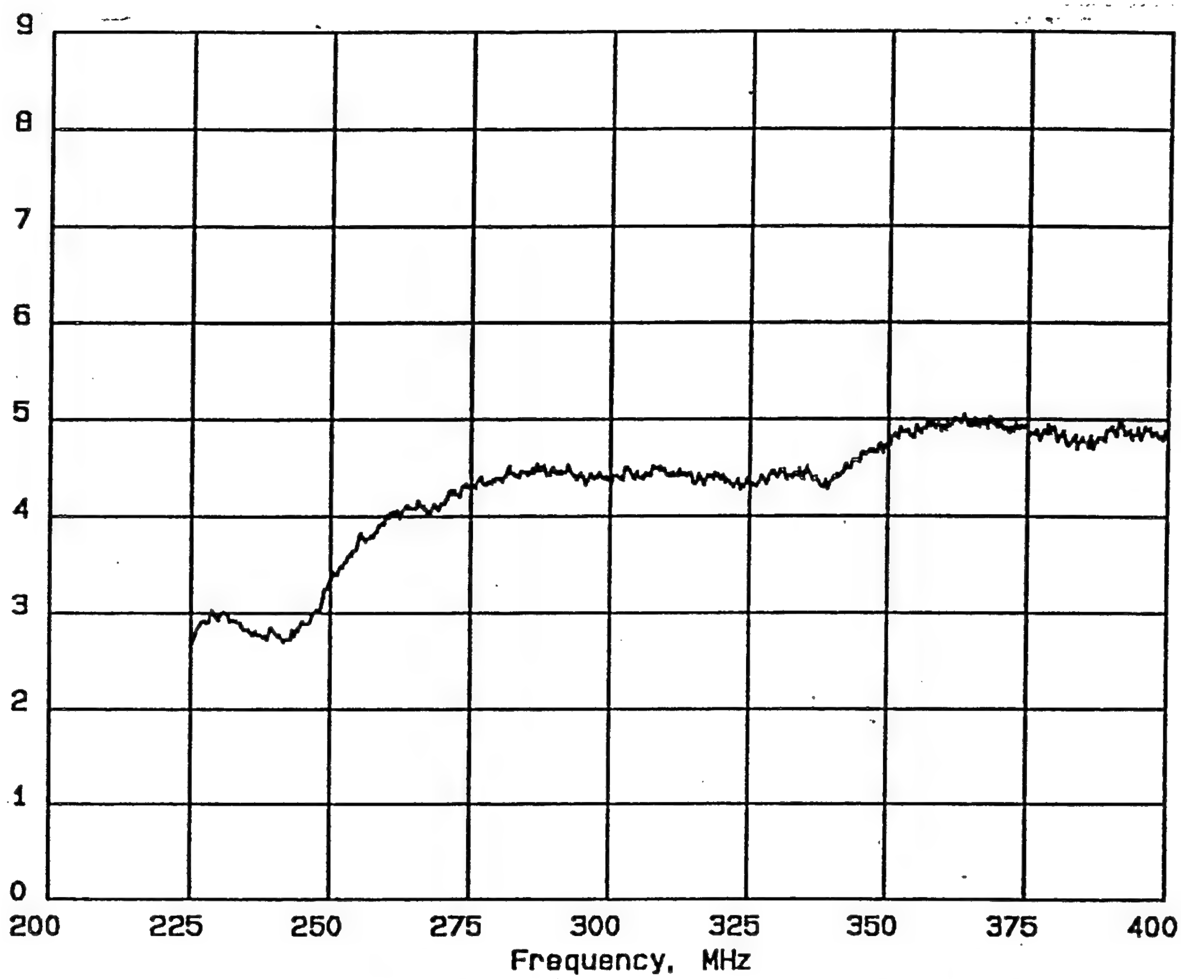


FIGURE 2-29
VSWR Versus Frequency UHF Antenna



Gain Vs Frequency : DPV-51 Prototype Antenna
Gain is in dBi

FIGURE 2-30

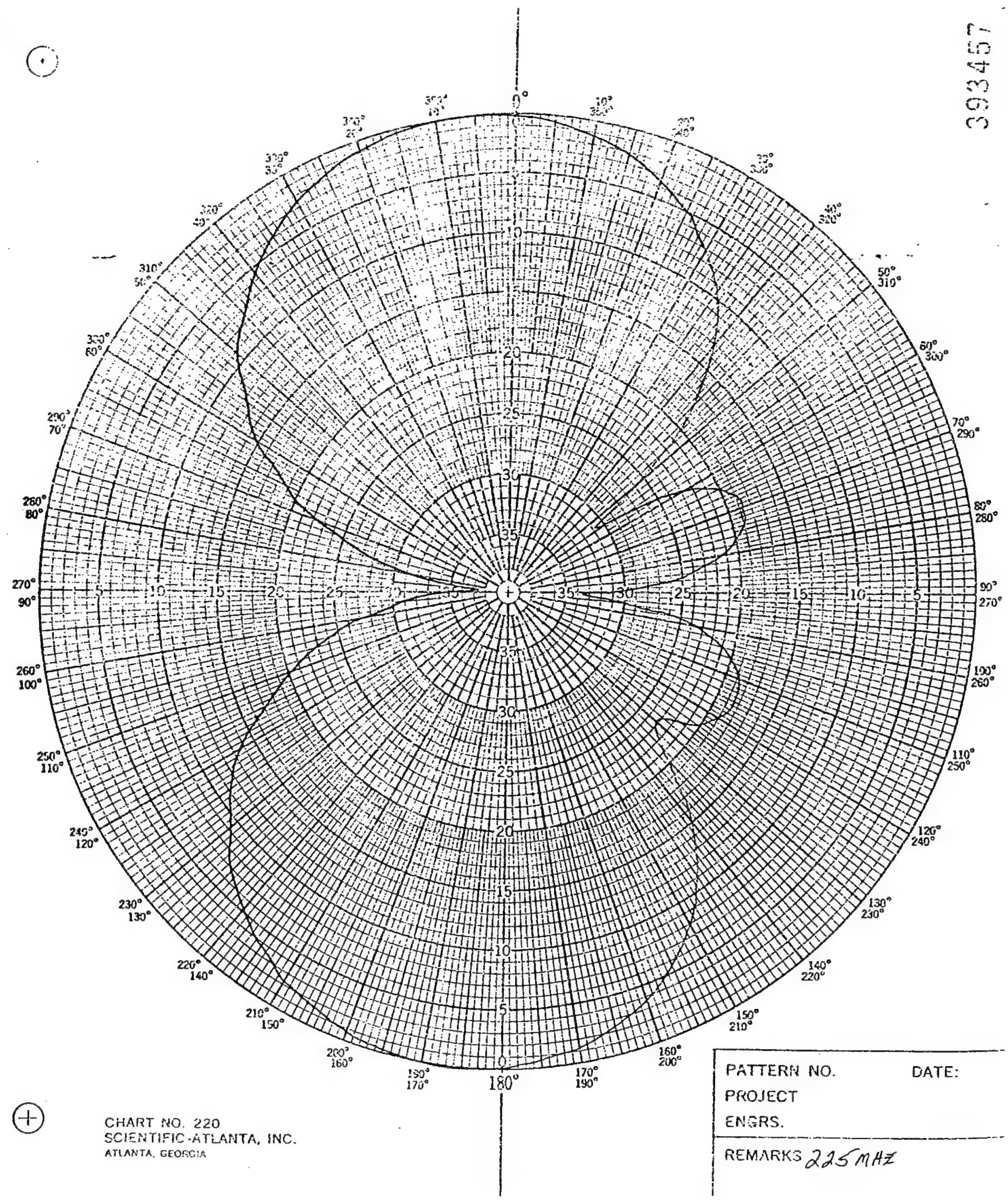


FIGURE 2-31
UHF E-Plane Patterns Configuration B
225 MHz

393459

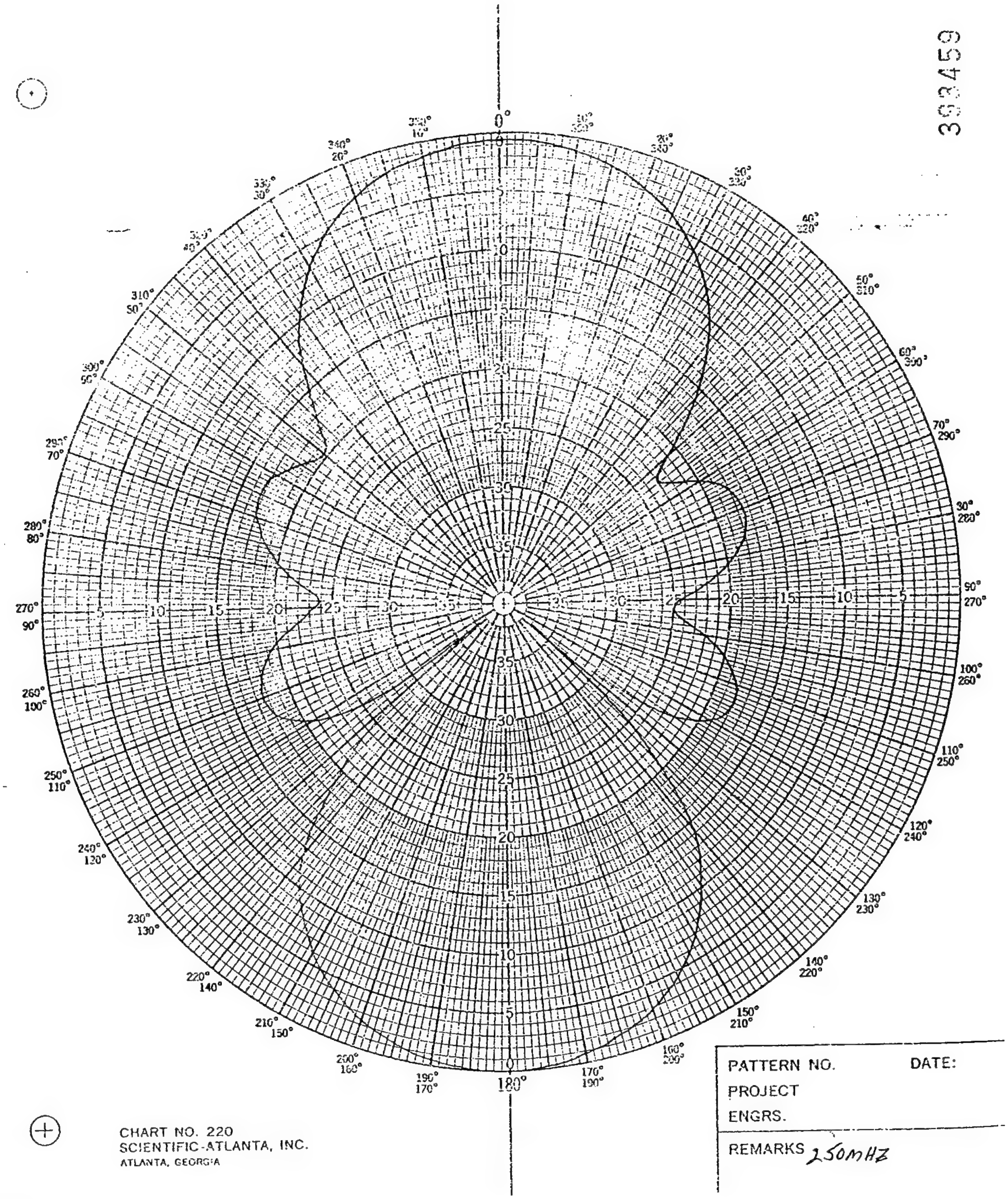


FIGURE 2-32
UHF E-Plane Patterns Configuration B
250 MHz

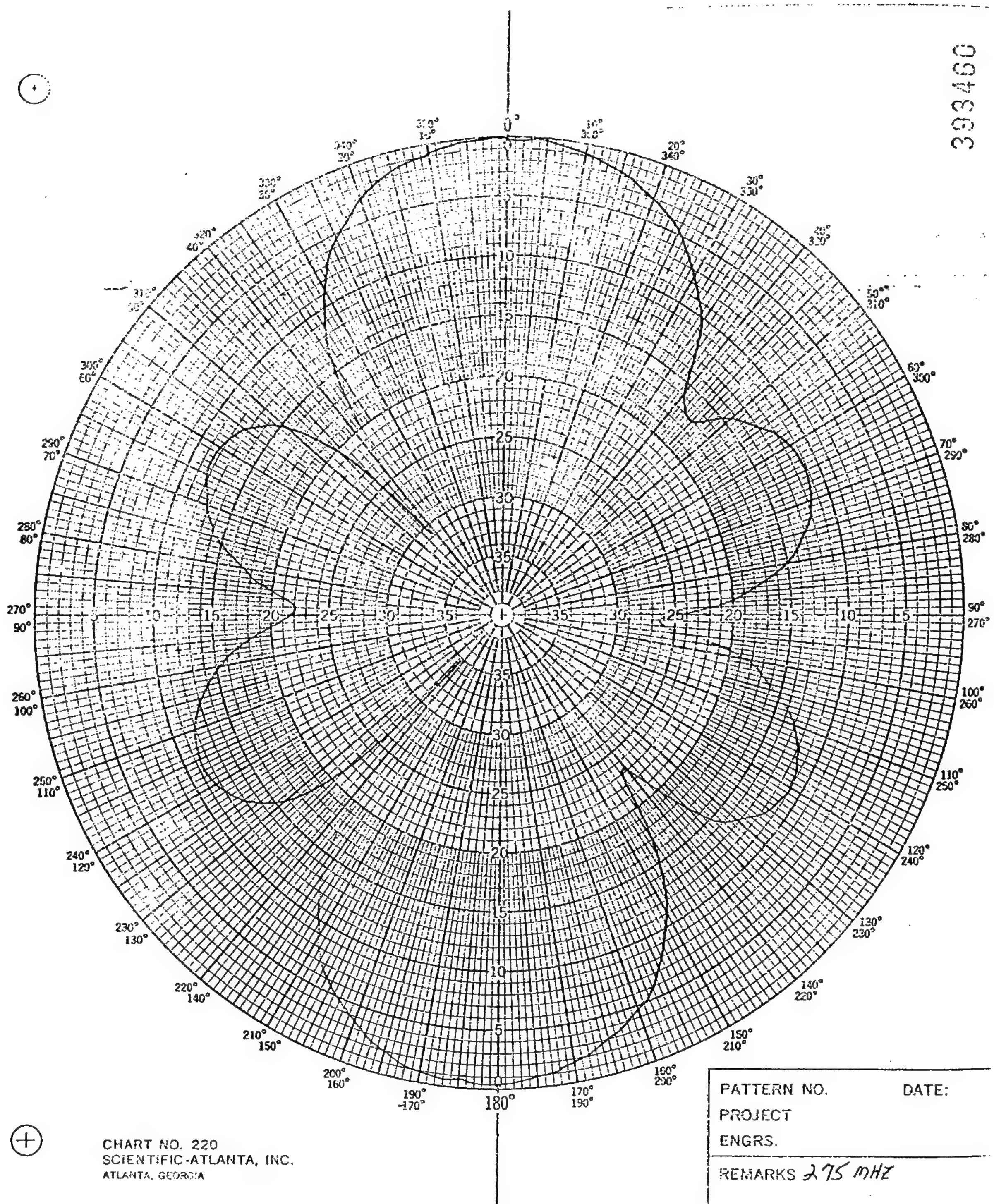


FIGURE 2-33
UHF E-Plane Patterns Configuration B
275 MHz

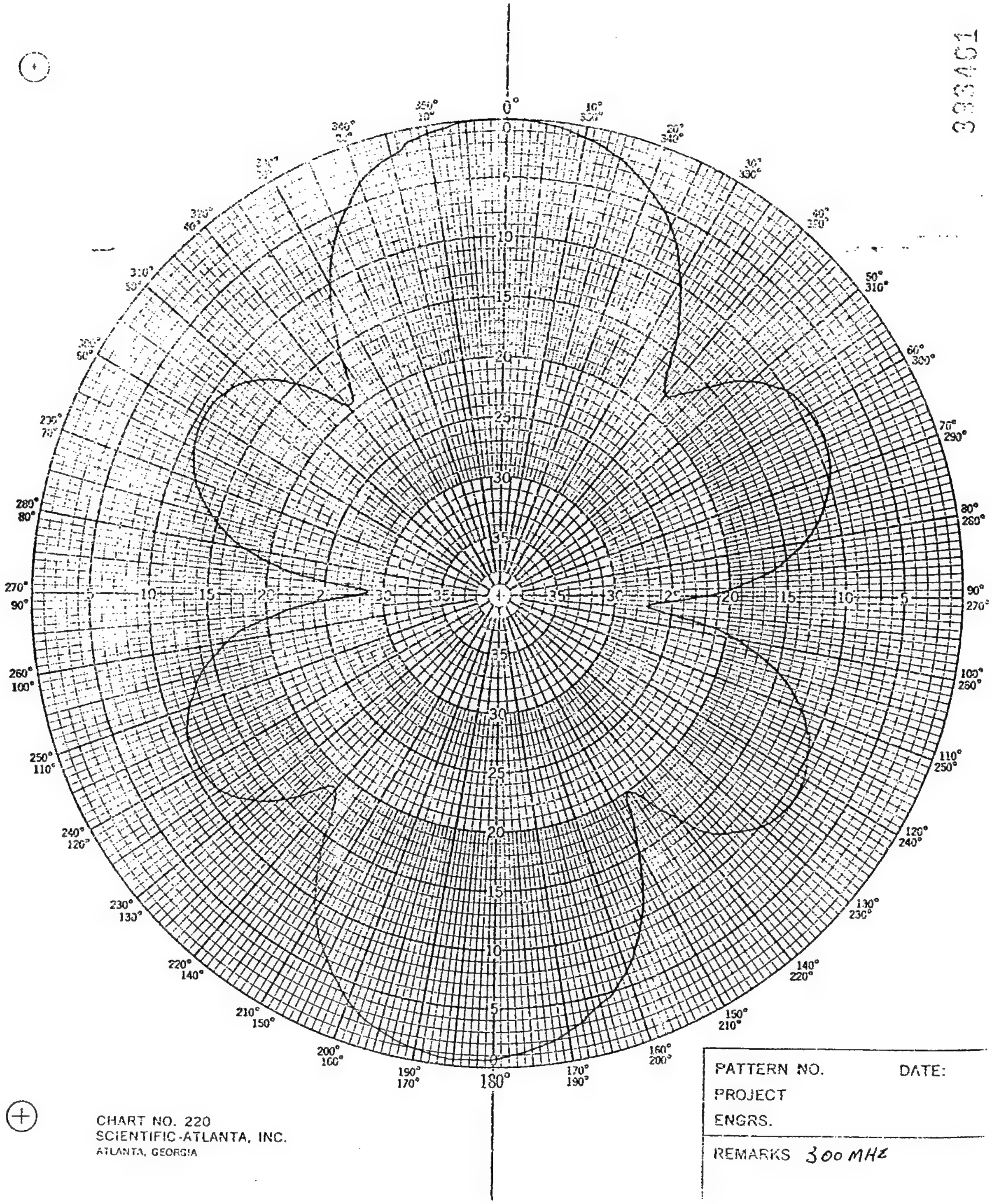


FIGURE 2-34
UHF E-Plane Patterns Configuration B
300 MHz

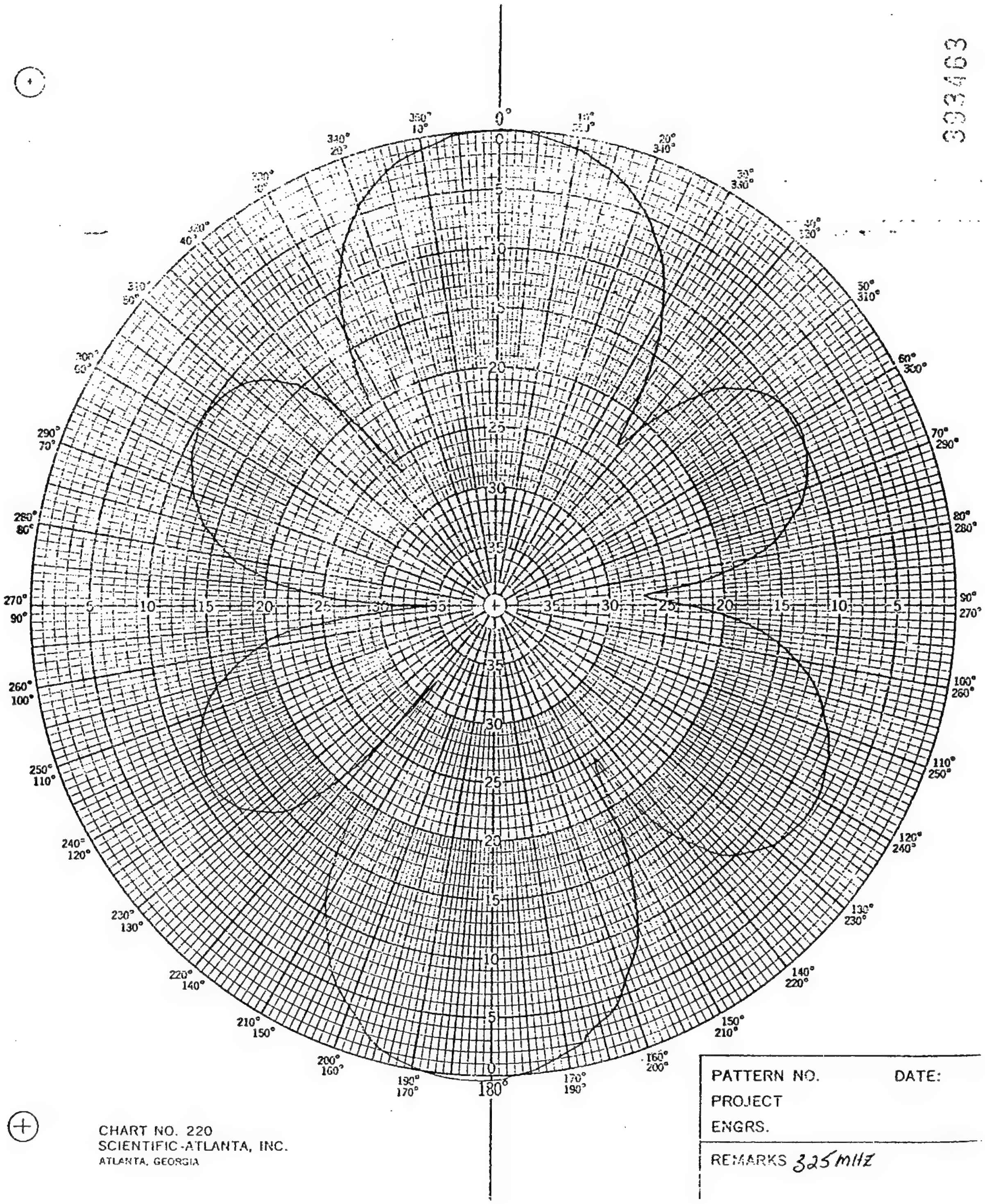


FIGURE 2-35
UHF E-Plane Patterns Configuration B
325 MHz

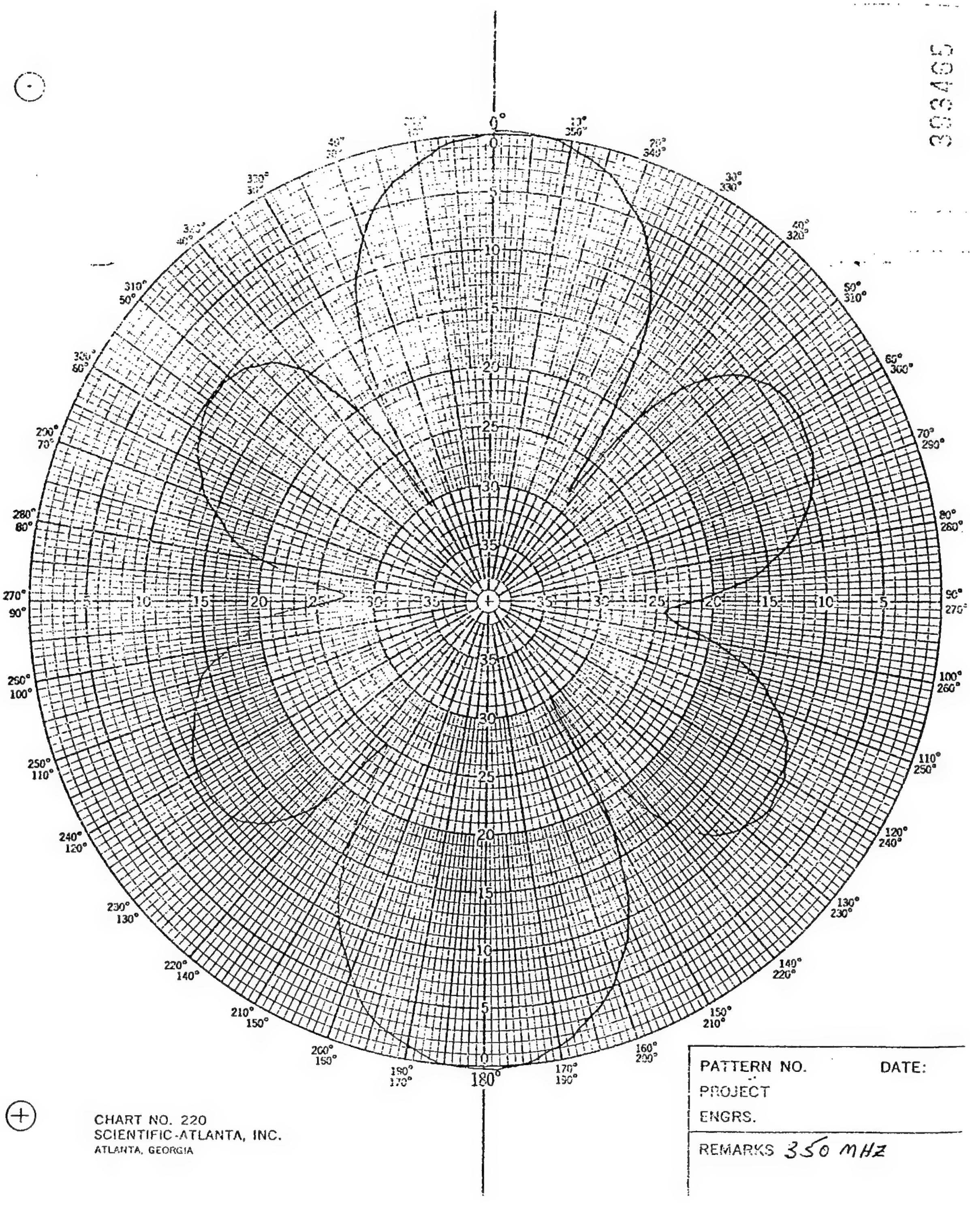


FIGURE 2-36
UHF E-Plane Patterns Configuration B
350 MHz

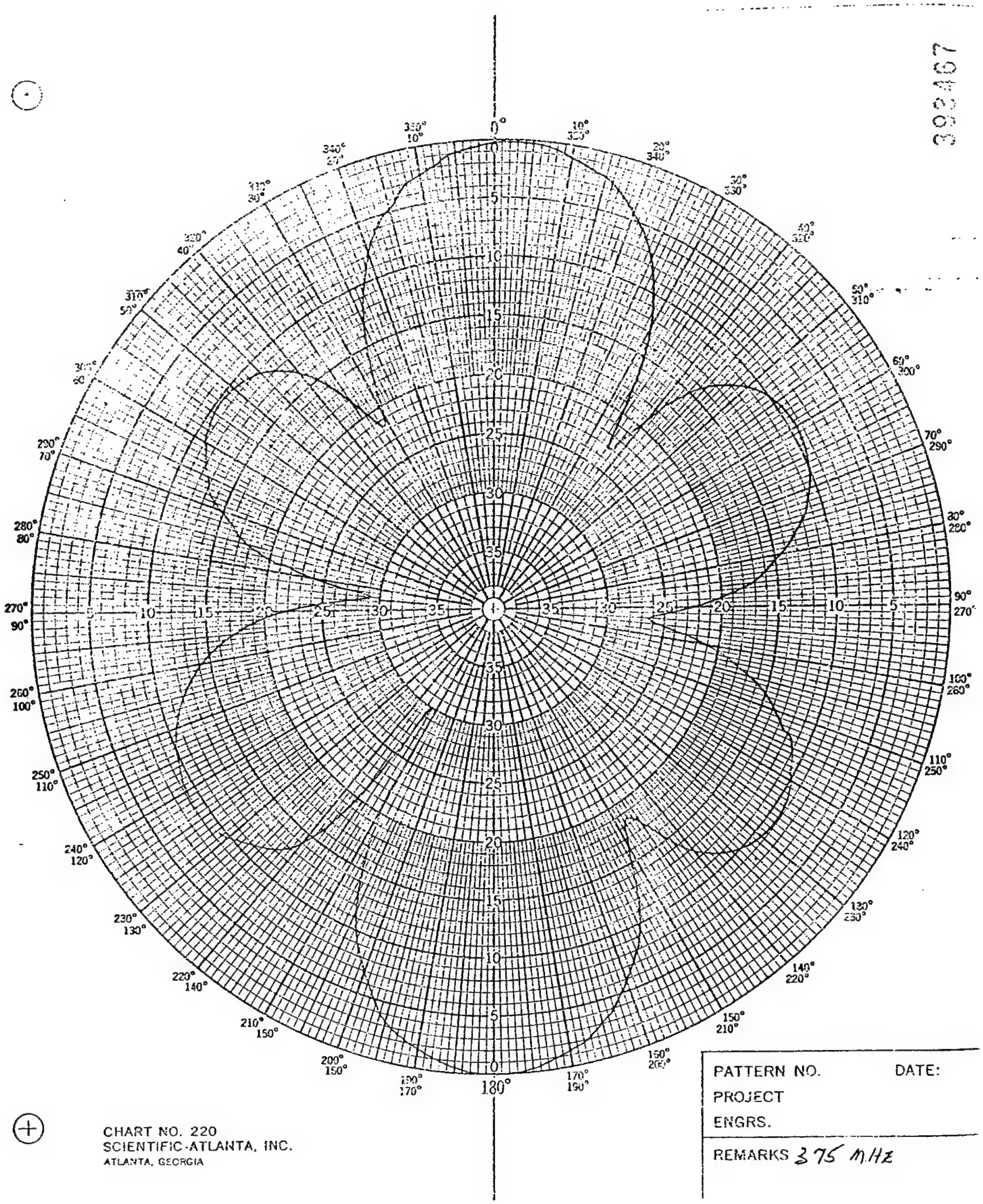


FIGURE 2-37
UHF E-Plane Patterns Configuration B
375 MHz

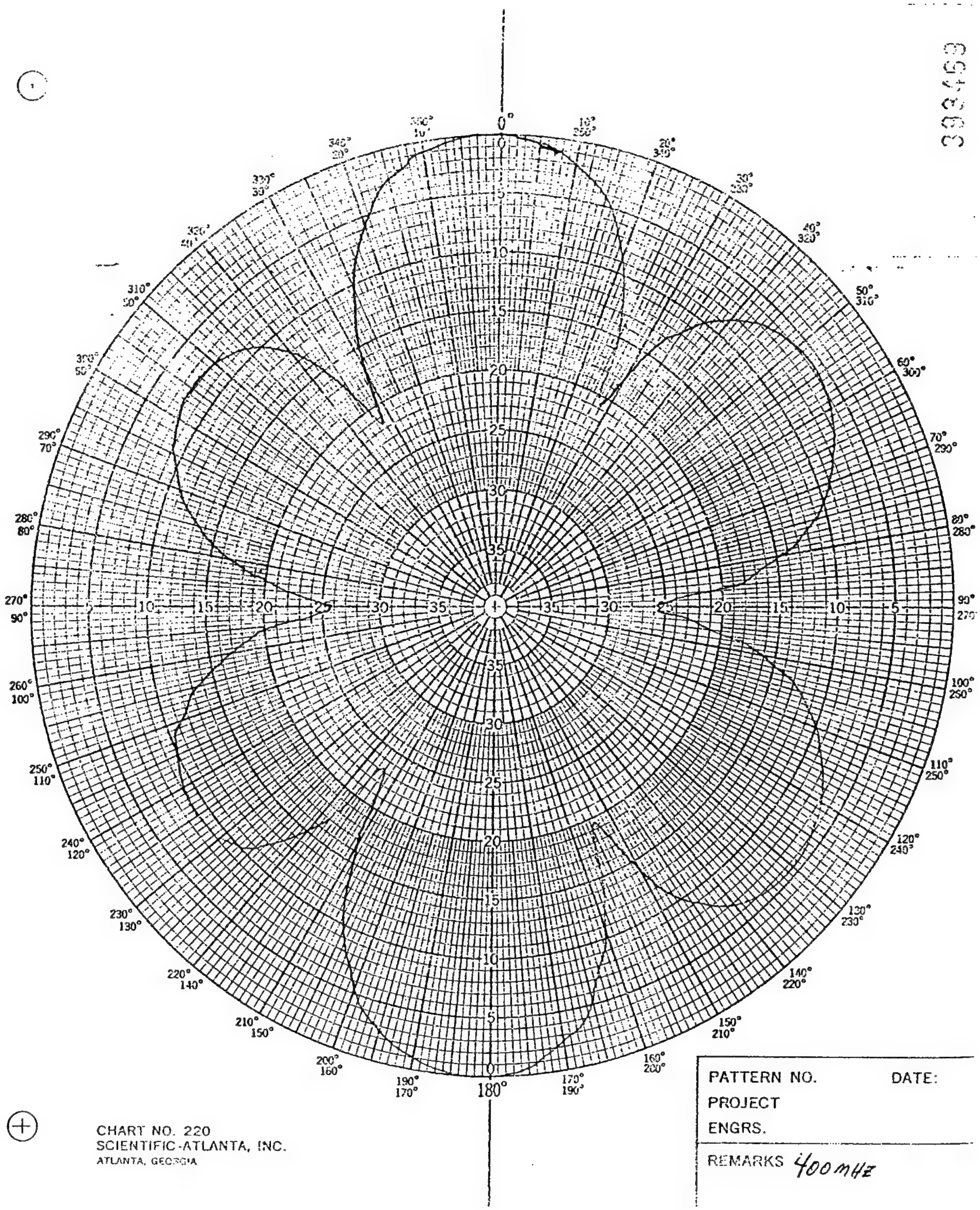


FIGURE 2-38
UHF E-Plane Patterns Configuration B
400 MHz

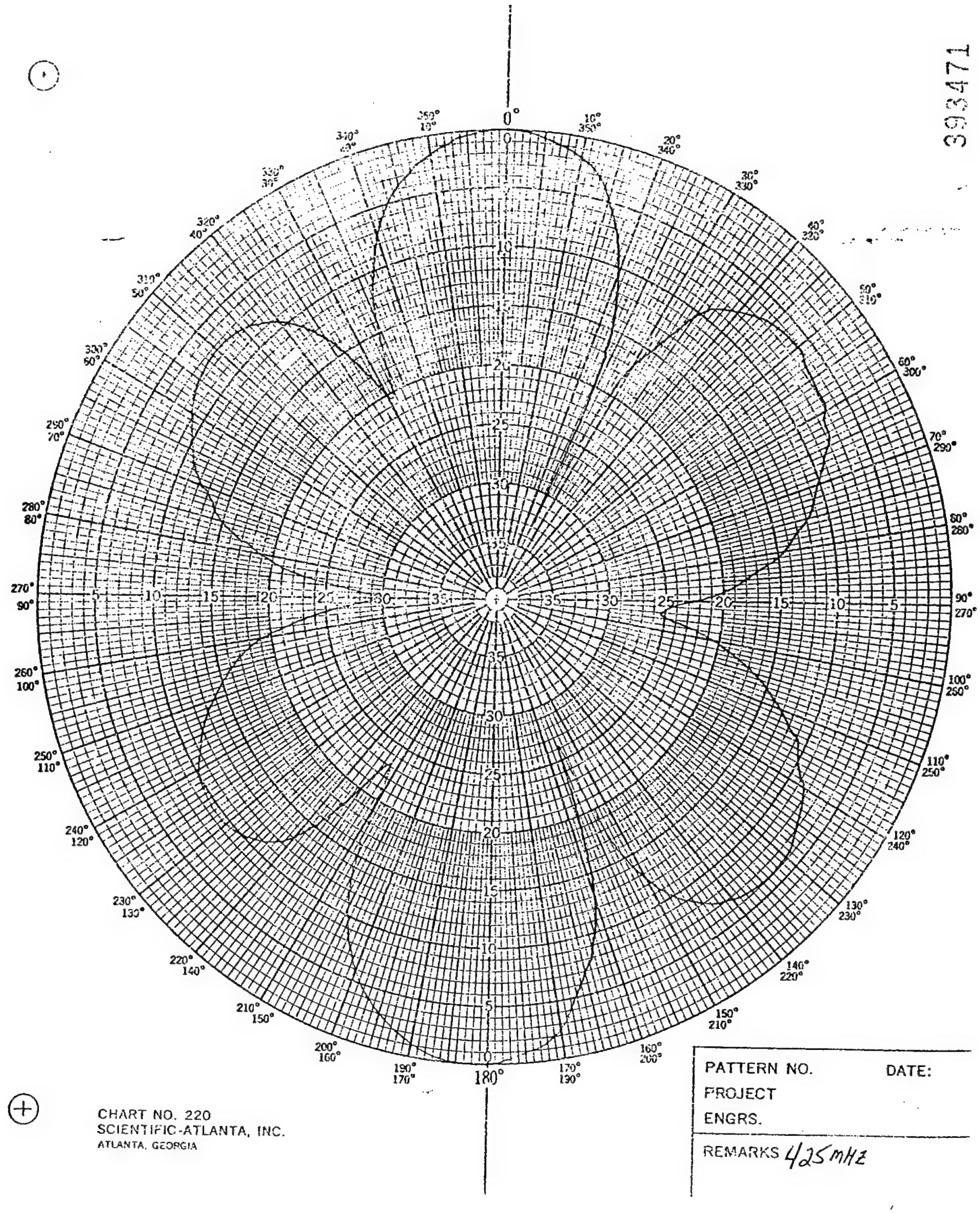


FIGURE 2-39
UHF E-Plane Patterns Configuration B
425 MHz

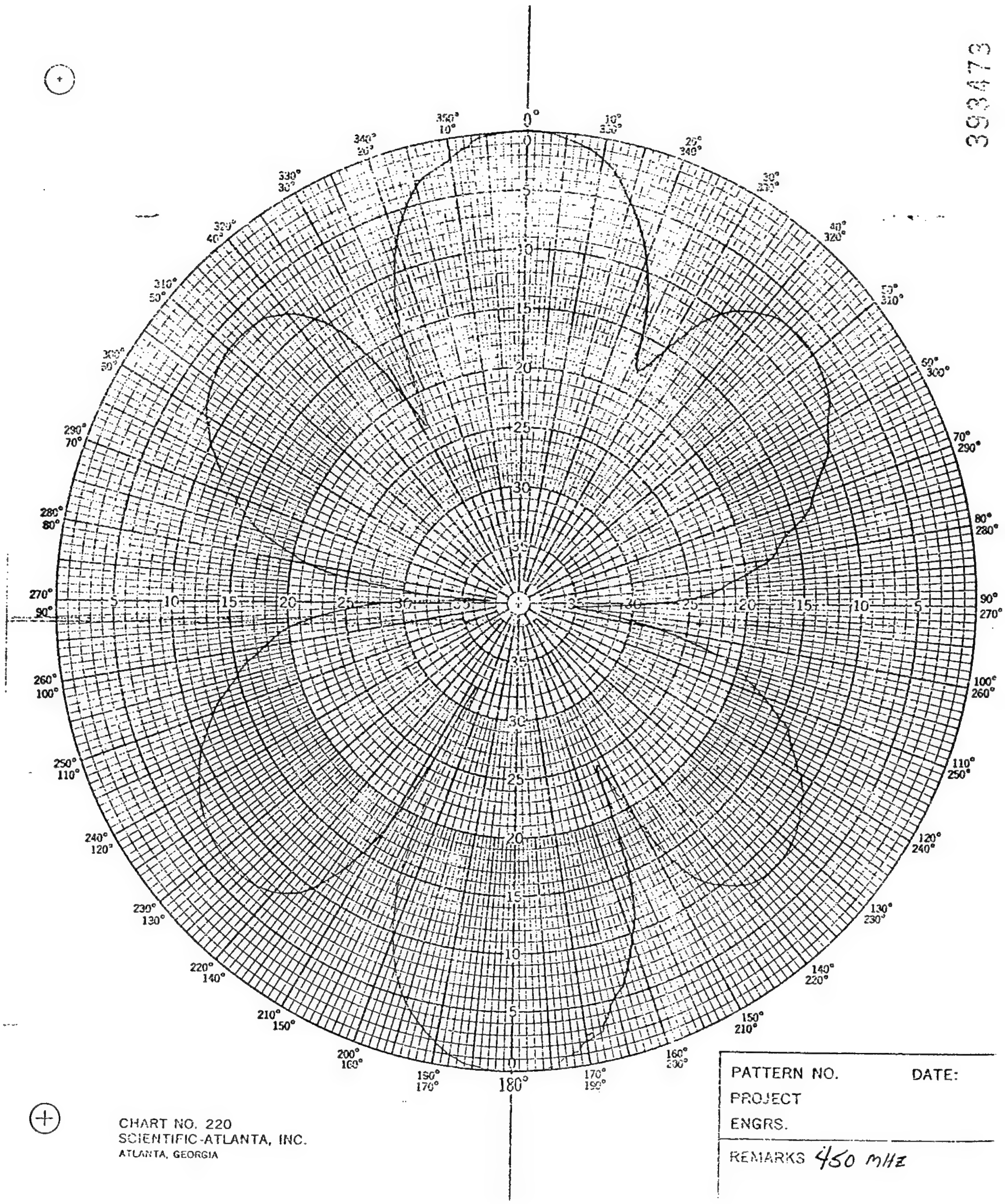


FIGURE 2-40
UHF E-Plane Patterns Configuration B
450 MHz

3.0 CONFIGURATION C

3.1 Background

This configuration started as a fat monopole fed over a radial counterpoise as did configuration A. Configuration C differed from Configuration A in that it was a UHF antenna inside a VHF antenna whereas configuration A was a UHF antenna mounted above a VHF antenna. Configuration C was changed to dipoles instead of monopoles and radial counterpoises following the results of the radial investigations of configuration A.

One arrangement studied and reported on in the interim report looked very promising. However, when it came down to incorporating all the matching networks and getting both the VHF and UHF antennas to work at the same time, resonances occurred which we were not able to eliminate.

In view of this, the study of this configuration was again changed. It now consists of a UHF antenna mounted around a VHF antenna. We have used this concept previously where the UHF antenna had to mount on a ship's mast with the mast being made of steel. Here the omnidirectional pattern is maintained by using four dipoles equally spaced about the mast. The dipoles stand off about a quarter wavelength at center frequency from the mast.

As long as the diameter of the ship's mast is below a half wavelength at the highest frequency, the patterns provide good omnidirectional performance.

If both the diameter of the mast and the spacing between the UHF dipoles and the mast are decreased sufficiently then fairly good omnidirectional coverage is achieved by using only two dipoles instead of four. These closer spacings produce UHF impedances that are more difficult to match. These two dipoles may be viewed as one in front of the mast (or VHF element) and the second behind it. In our case an elevation array of the vertical dipoles is required to achieve the desired gain. Figure 3-1 shows the antenna with approximate dimensions.

Section 3.2 discusses the VHF performance of the antenna providing impedances, patterns and gain. The properties of the UHF antenna are given in section 3.3 along with the approach taken to solve the impedance problem.

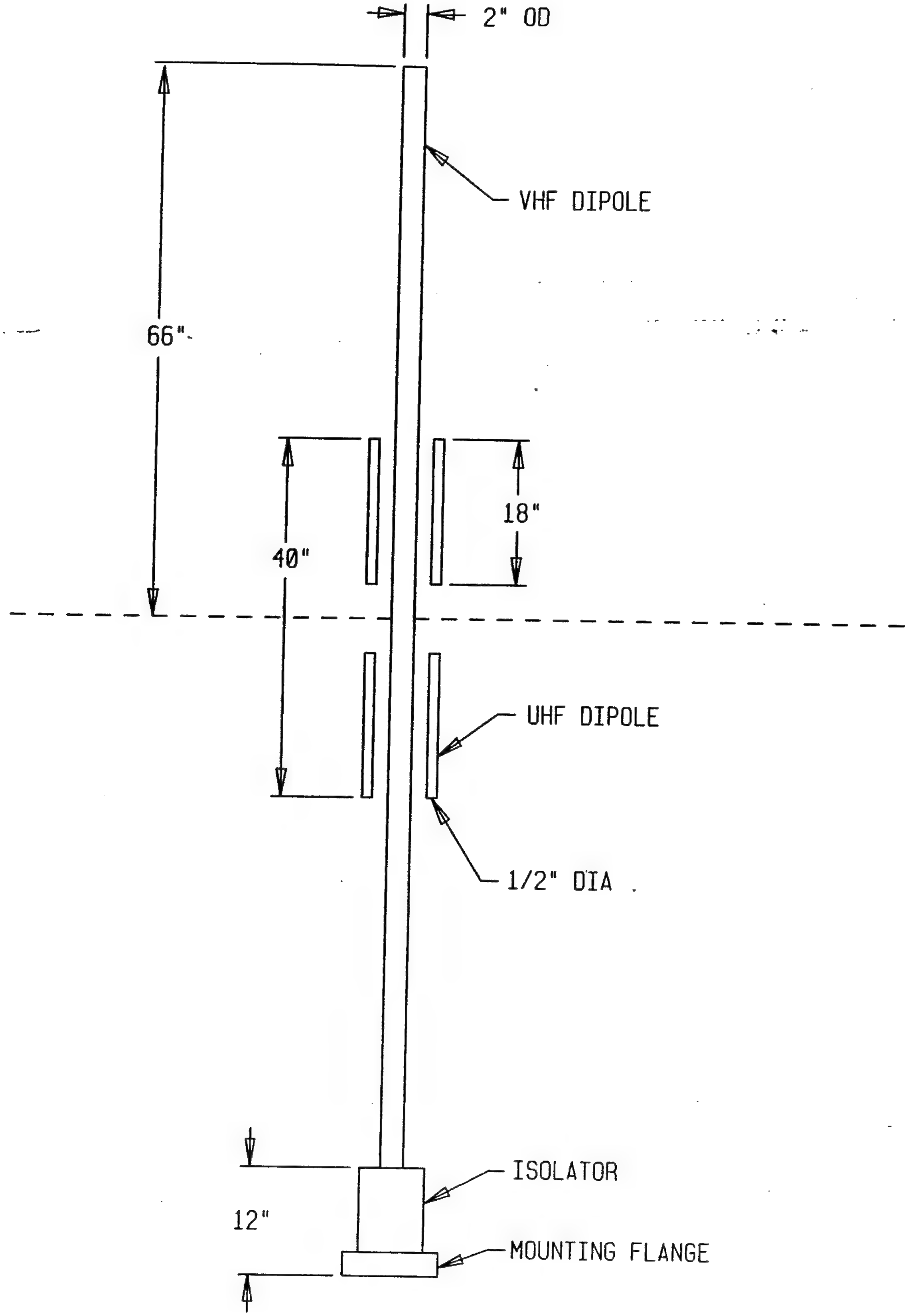


FIGURE 3-1
Configuration C

3.2 VHF Performance

The VHF portion of the antenna was analyzed using NEC-3. Table 3-1 lists these impedances as a function of frequency over the 30 to 90 MHz bands. These are plotted on a Smith Chart and shown in figure 3-2. In order to verify data, a model was built and tested. The results of the tests are graphically presented in figure 3-3. As can be seen by comparing the theoretical and measured data, the results are in good agreement with the frequencies where the impedance loci cross the real axis being very close. An initial try at matching these impedances to 50 ohms was made using a Tchebyscheff transformer configuration (that is, shunt inductance across antenna, series capacitance, shunt capacitance and series inductance). The resulting impedances are shown in figure 3-4 followed by a plot of VSWR versus frequency in figure 3-5. As shown the VSWR is about 3.3:1 maximum; however, this may eventually be improved with a more detailed approach.

E-Plane radiation patterns for 30, 50, 70 and 90 MHz are shown in figures 3-6 through 3-9. These were computed using NEC-3. Additional patterns are provided in Appendix D. The patterns are very typical of what one would expect with the gain varying from 1.95 dBi at 30 MHz to 4 dBi at 90 MHz.

The prototype antenna was measured at the test site for gain and the results are given in figure 3-10. The gain is about 2 dB less than was expected. Some of this may be due to the isolator at the base of the antenna.

- - - INPUT IMPEDANCE DATA - - -
SOURCE SEGMENT NO. 26
NORMALIZATION FACTOR= 0.50000E+02

FREQ.	- - UNNORMALIZED IMPEDANCE - -				- - NORMALIZED IMPEDANCE - -				VSWR
	RESISTANCE	REACTANCE	MAGNITUDE	PHASE	RESISTANCE	REACTANCE	MAGNITUDE	PHASE	
MHZ	OHMS	OHMS	OHMS	DEGREES				DEGREES	
30.000	0.26142E+02	-0.23390E+03	0.23536E+03	-83.62	0.52285E+00	-0.46780E+01	0.47072E+01	-83.62	44.27
34.000	0.36958E+02	-0.15027E+03	0.15474E+03	-76.18	0.73916E+00	-0.30053E+01	0.30949E+01	-76.18	14.24
38.000	0.51665E+02	-0.73288E+02	0.89668E+02	-54.82	0.10333E+01	-0.14658E+01	0.17934E+01	-54.82	3.82
42.000	0.71970E+02	0.96148E+00	0.71976E+02	0.77	0.14394E+01	0.19230E-01	0.14395E+01	0.77	1.44
46.000	0.10058E+03	0.75461E+02	0.12574E+03	36.88	0.20115E+01	0.15092E+01	0.25147E+01	36.88	3.34
50.000	0.14187E+03	0.15242E+03	0.20823E+03	47.05	0.28374E+01	0.30484E+01	0.41646E+01	47.05	6.31
54.000	0.20313E+03	0.23273E+03	0.30891E+03	48.88	0.40626E+01	0,46545E+01	0.61782E+01	48.88	9.54
58.000	0.29638E+03	0.31372E+03	0.43158E+03	46.63	0.59277E+01	0.62744E+01	0.86317E+01	46.63	12.66
62.000	0.44004E+03	0.38268E+03	0.58316E+03	41.01	0.88008E+01	0.76535E+01	0.11663E+02	41.01	15.51
66.000	0.65341E+03	0.40123E+03	0.76677E+03	31.55	0.13068E+02	0.80245E+01	0.15335E+02	31.55	18.02
70.000	0.91867E+03	0.28774E+03	0.96268E+03	17.39	0.18373E+02	0.57548E+01	0.19254E+02	17.39	20.18
74.000	0.10999E+04	-0.21646E+02	0.11001E+04	-1.13	0.21999E+02	-0.43293E+00	0.22003E+02	-1.13	22.01
78.000	0.10291E+04	-0.38762E+03	0.10996E+04	-20.64	0.20581E+02	-0.77525E+01	0.21993E+02	-20.64	23.51
82.000	0.78702E+03	-0.59256E+03	0.98515E+03	-36.98	0.15740E+02	-0.11851E+02	0.19703E+02	-36.98	24.69
86.000	0.55137E+03	-0.63121E+03	0.83812E+03	-48.86	0.11027E+02	-0.12624E+02	0.16762E+02	-48.86	25.53
90.000	0.38144E+03	-0.59049E+03	0.70298E+03	-57.14	0.76288E+01	-0.11810E+02	0.14060E+02	-57.14	26.00

TABLE 3-1
Impedances of VHF Antenna

TITLE Computed Using NEC-3 UV.BAT D:\ECOM4 DATE 5 Mar 98

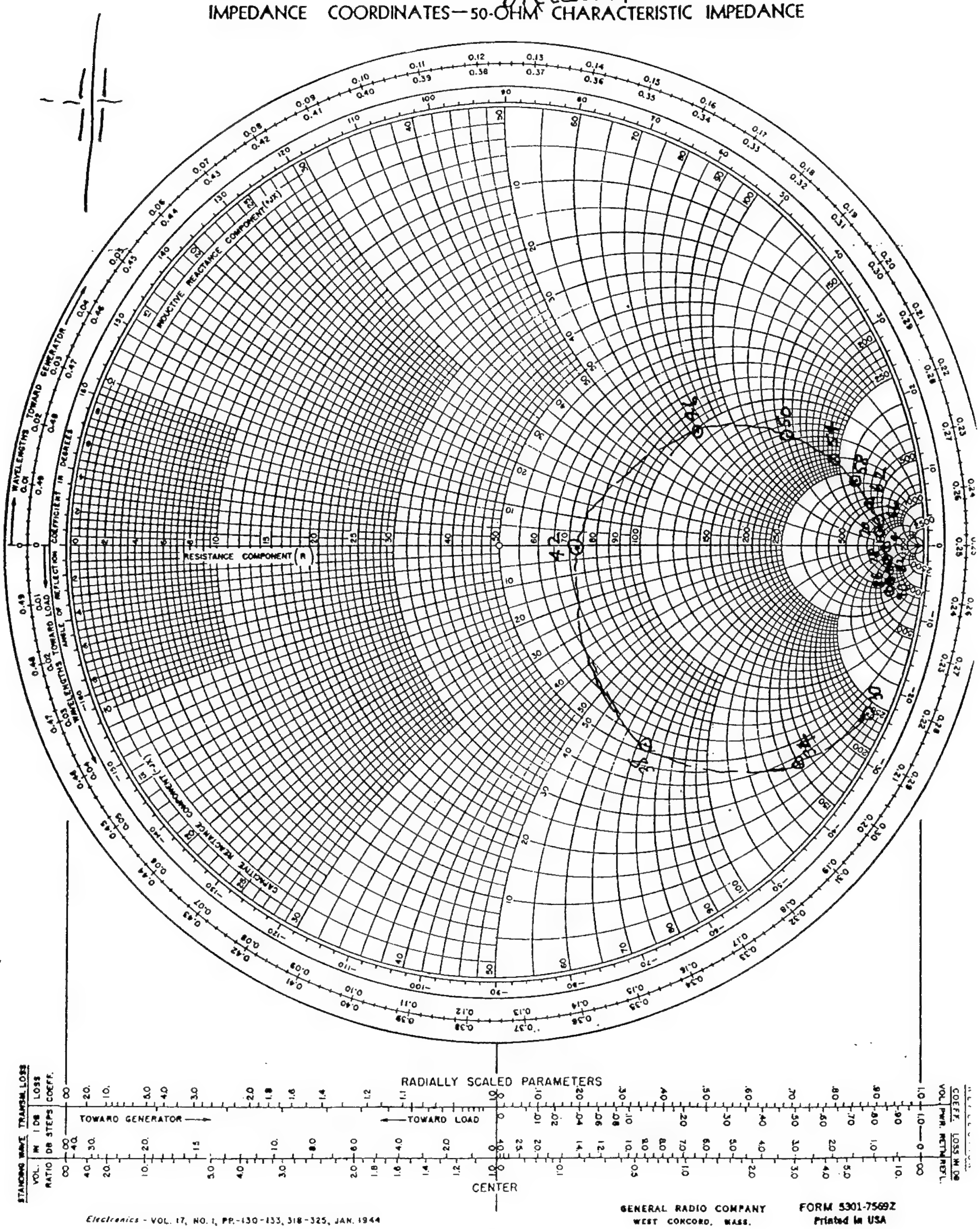


FIGURE 3-2
Smith Chart Plot of VHF Antenna Impedances

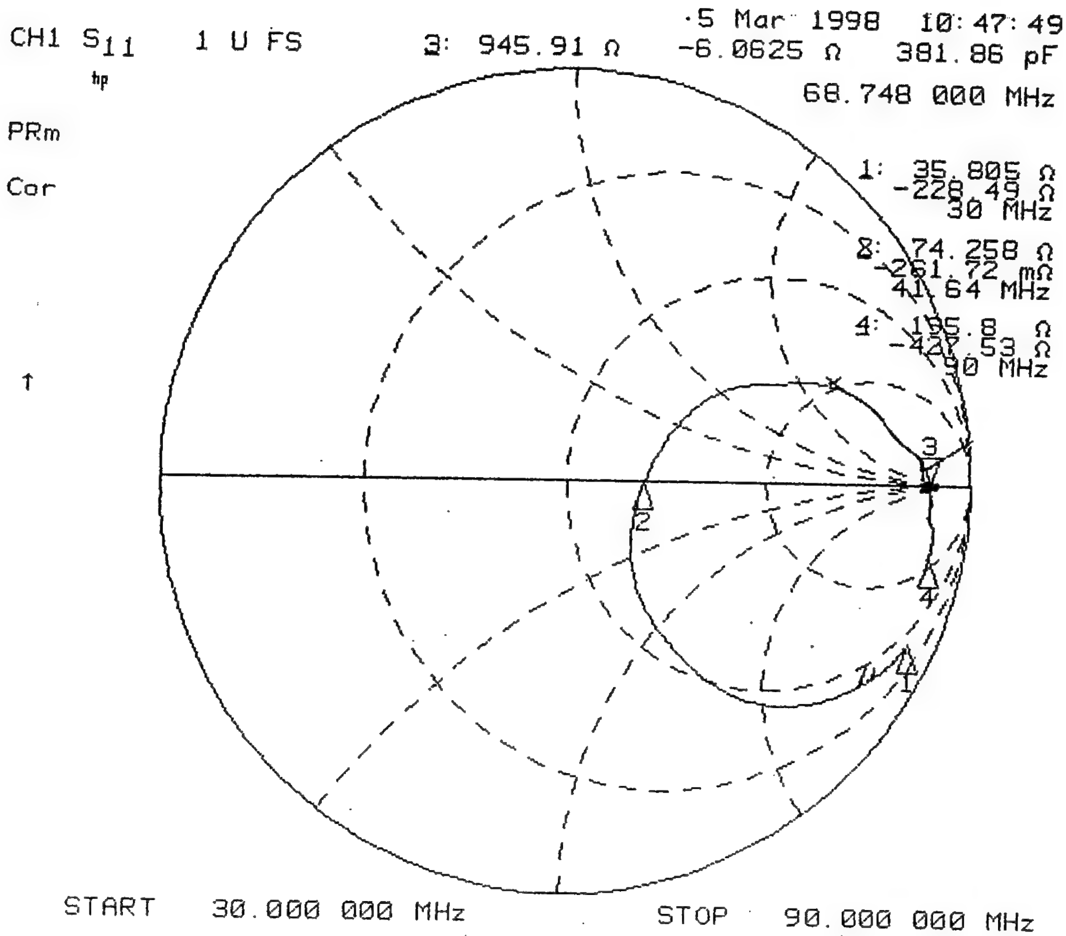


FIGURE 3-3
Measured Impedances of VHF Antenna

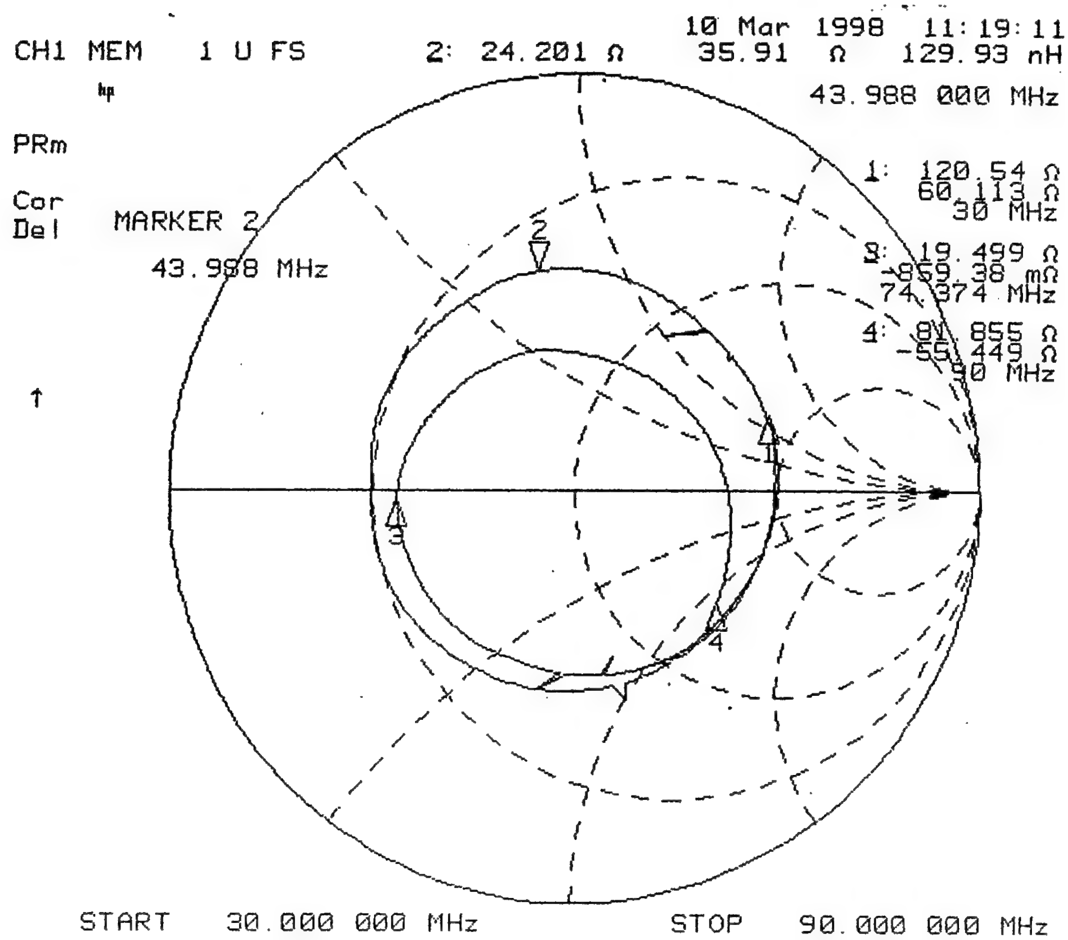


FIGURE 3-4
Impedances of VHF Antenna With Matching Unit

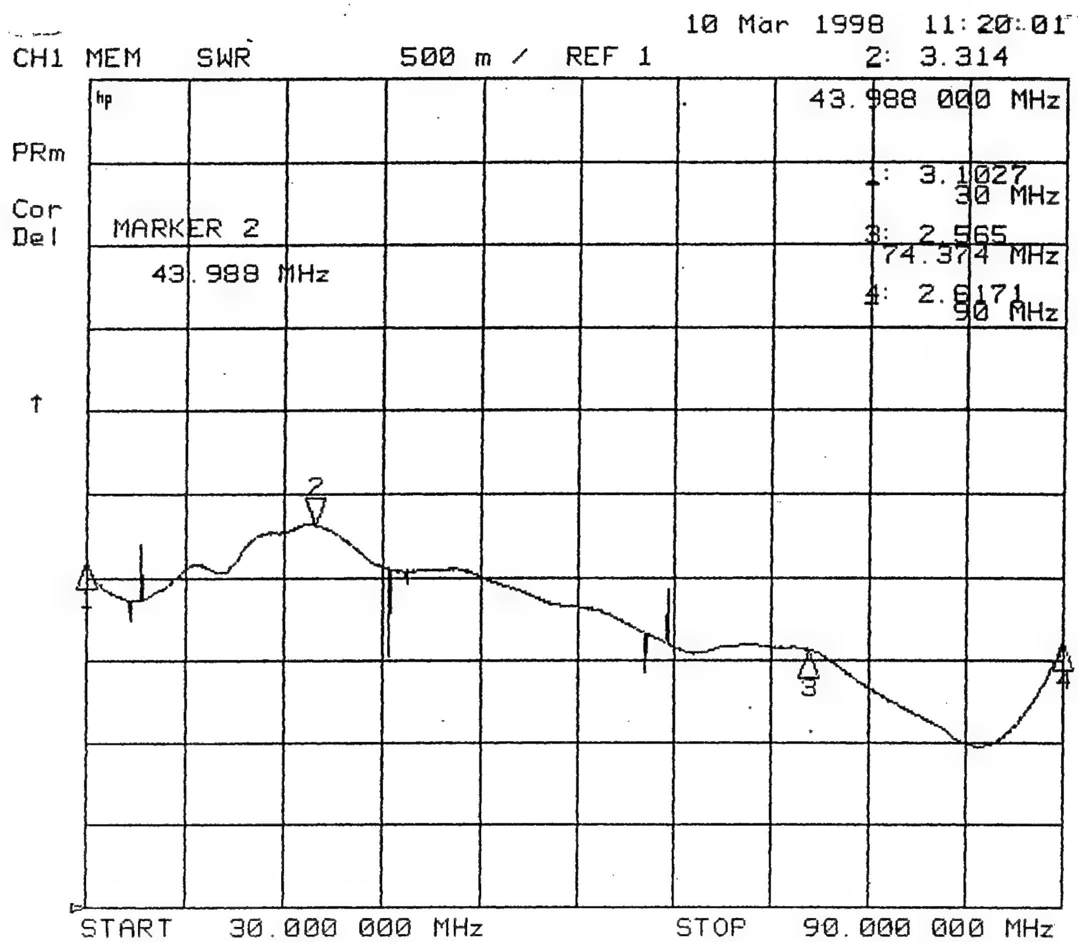
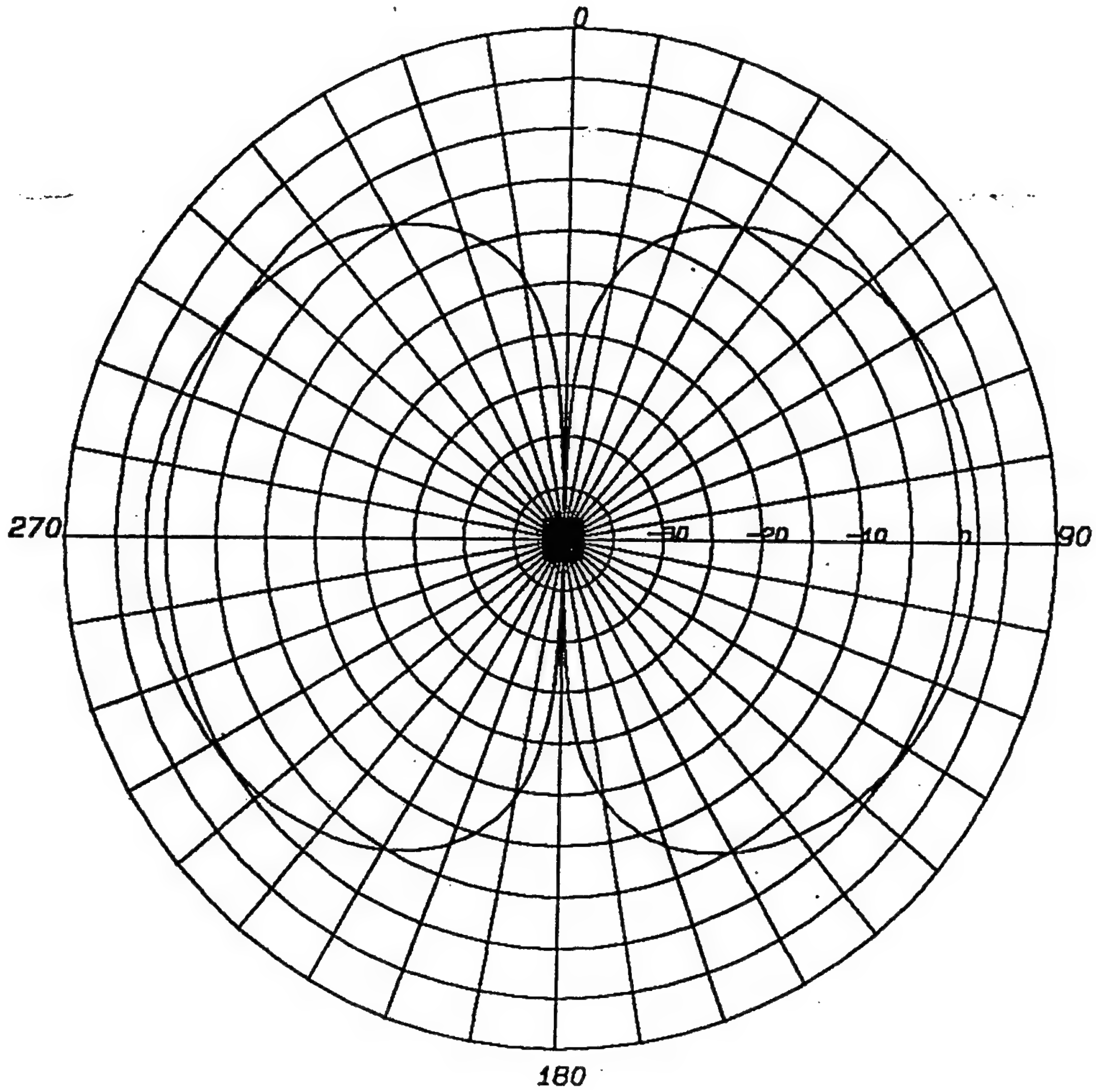


FIGURE 3-5
VSWR Versus Frequency of VHF Antenna With Matching Network

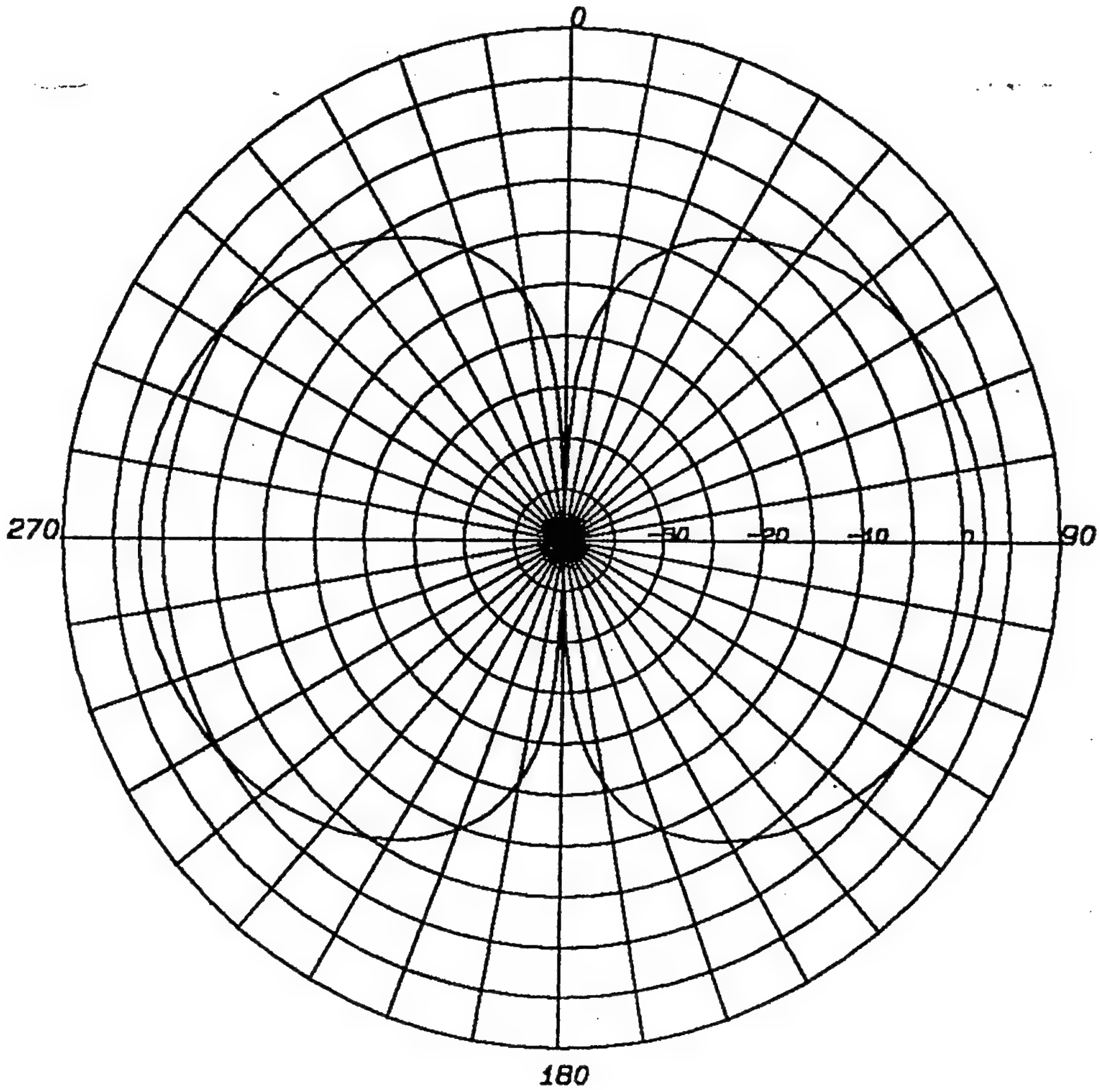
Antenna Products Corp.
Mineral Wells, Texas



1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 30 MHz : Scale is dBi
Gain = 1.95 dBi : Theta = 88 Degrees

FIGURE 3-6

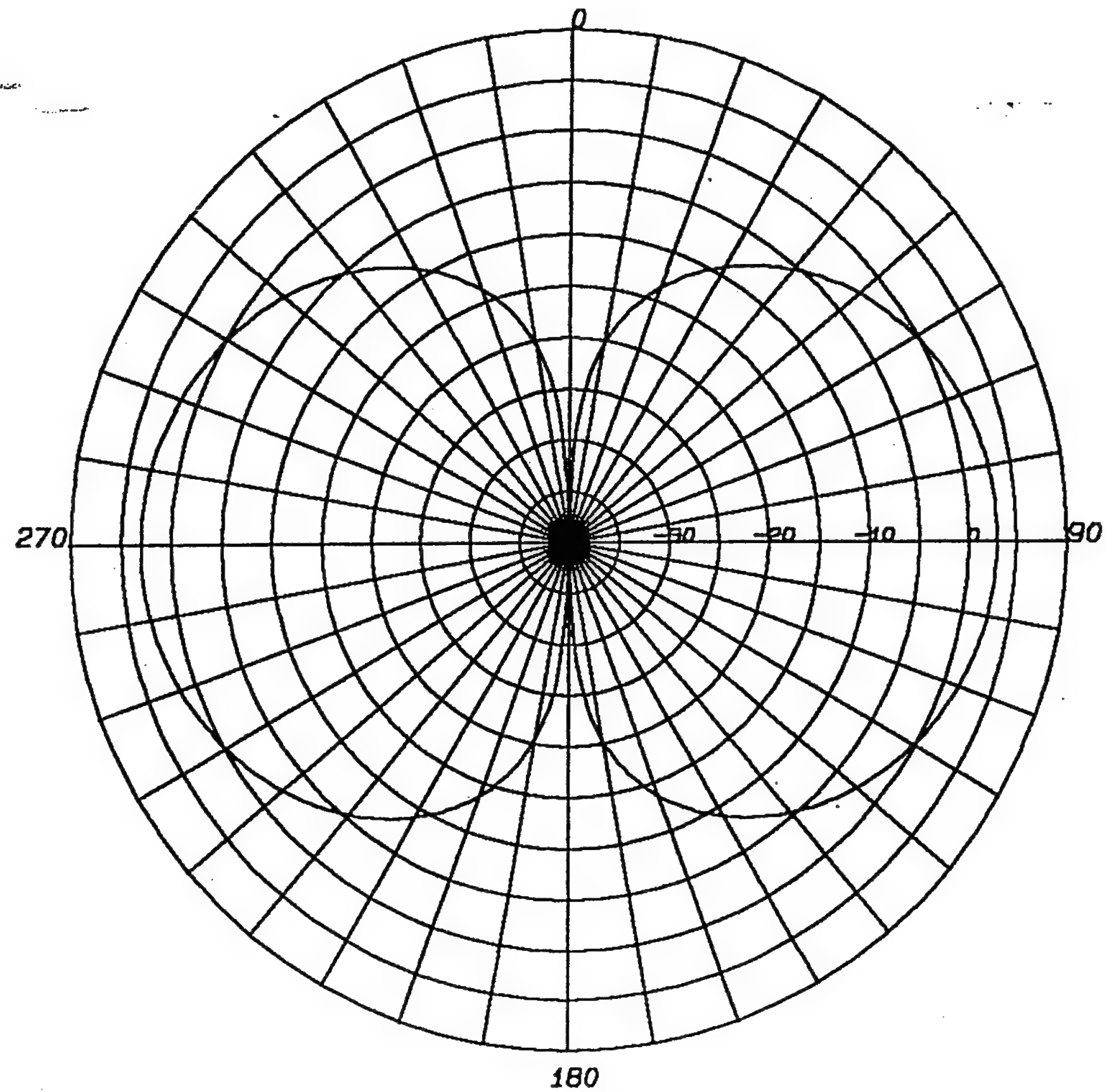
Antenna Products Corp.
Mineral Wells, Texas



1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 50 MHz : Scale is dBi
Gain = 2.33 dBi : Theta = 89 Degrees

FIGURE 3-7

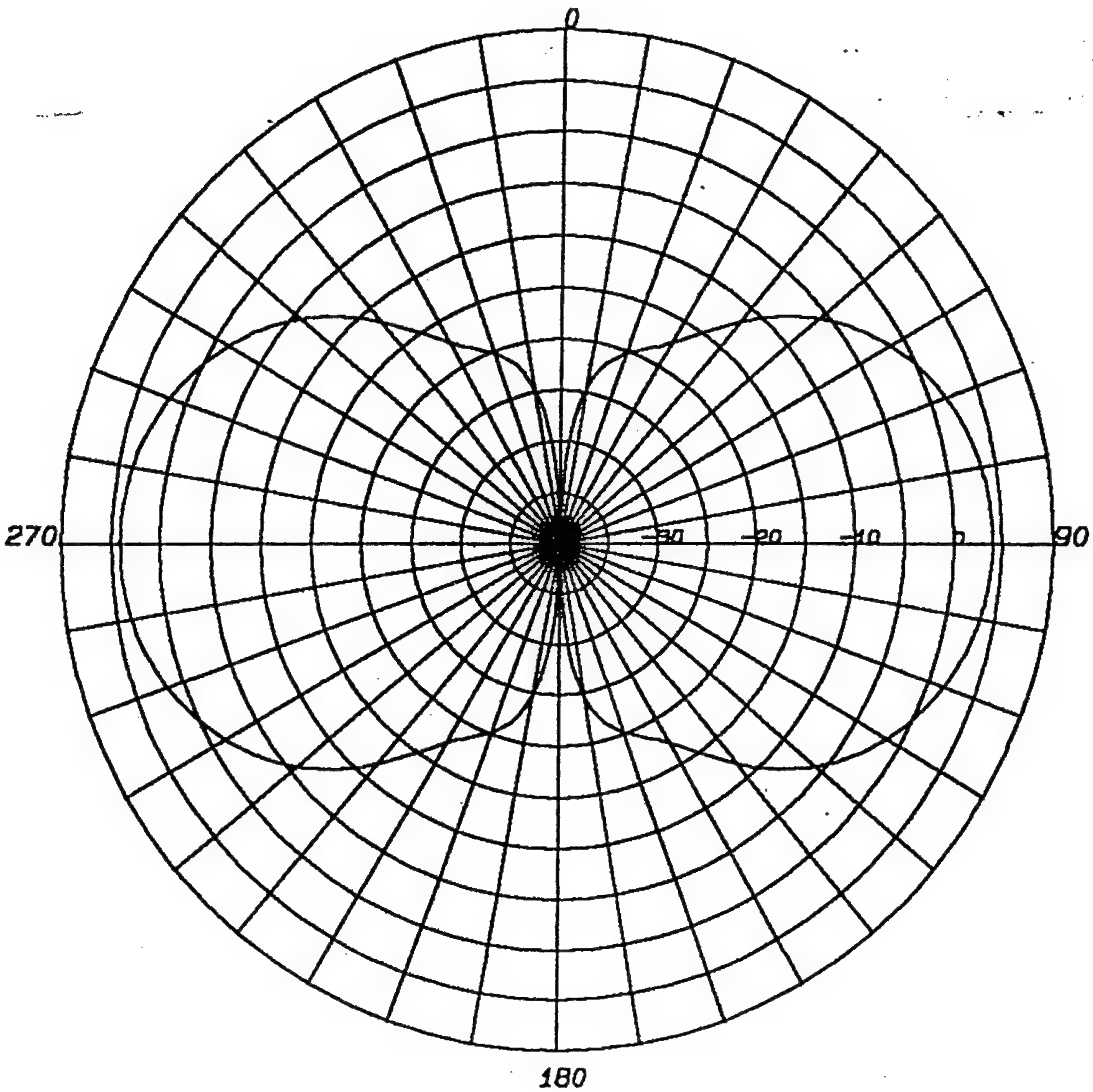
Antenna Products Corp.
Mineral Wells, Texas



1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 70 MHz : Scale is dBi
Gain = 3 dBi : Theta = 89 Degrees

FIGURE 3-8

Antenna Products Corp.
Mineral Wells, Texas



1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 90 MHz : Scale is dBi
Gain = 4.06 dBi : Theta = 90 Degrees

FIGURE 3-9

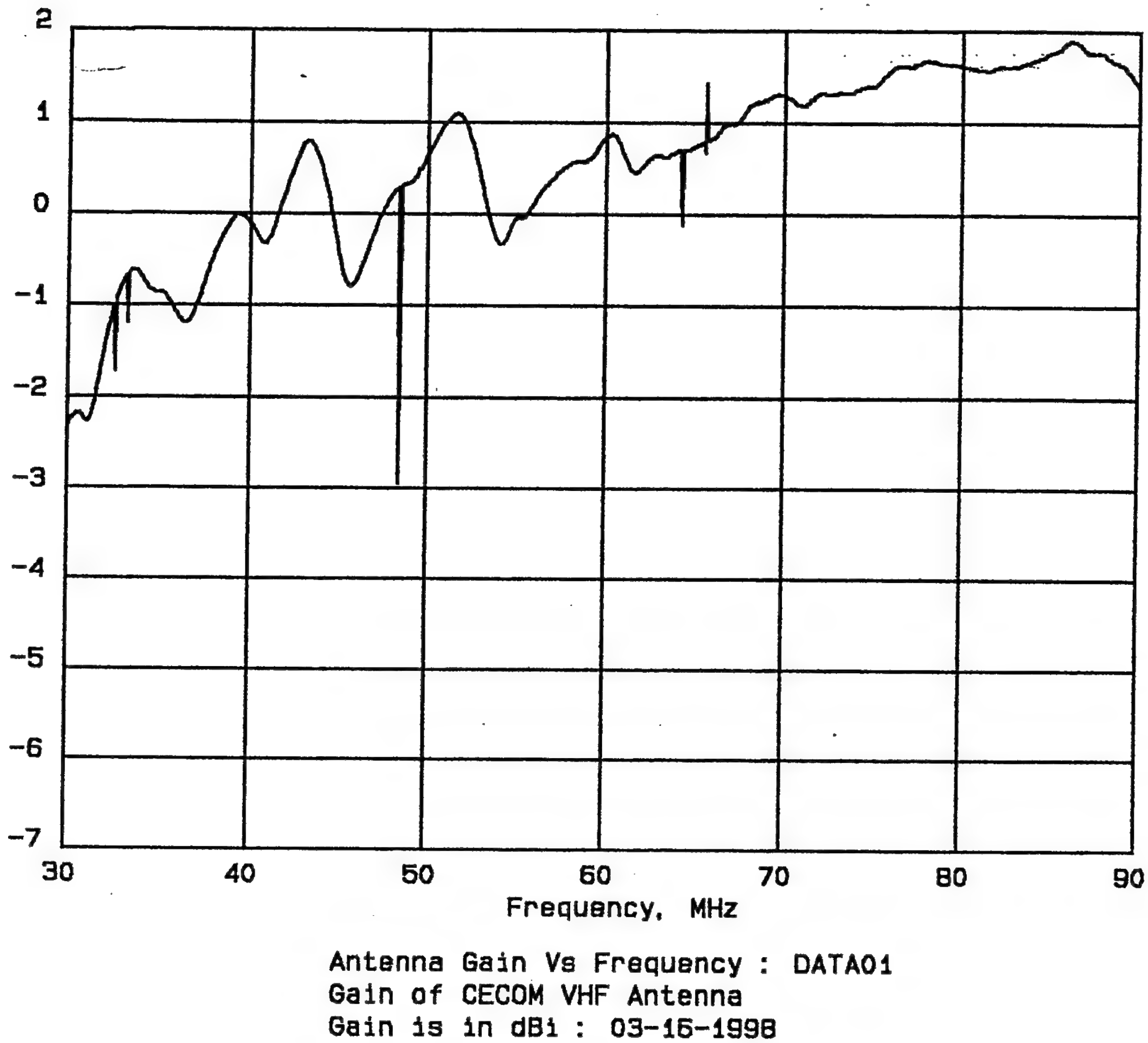

2
1
0
-1
-2
-3
-4
-5
-6
-7
30
40
50
60
70
80
90
Frequency, MHz
Antenna Gain Vs Frequency : DATA01
Gain of CECOM VHF Antenna
Gain is in dBi : 03-16-1998

FIGURE 3-10

3.3 UHF Performance

There are four UHF dipoles in the antenna system as shown in figure 3-1. It is desirable to keep the UHF dipoles close to the VHF element to conserve size and weight. In doing this the impedance is lowered and the loci of the impedance curve is expanded which makes the dipoles harder to match. Figure 3-11 shows the arrangement of a pair of dipoles and AMU's. It is desirable to match the dipole impedance to 50 ohms and to connect the two dipoles at the same level in series. A balun will then be used to transform the balanced impedance to unbalanced. A 100 ohm coaxial cable can then be wound on a Teflon form to serve as the shunt inductor for the VHF AMU. This arrangement enables getting the UHF upper coax to the lower VHF element where it can be combined in parallel with a similar arrangement for the lower UHF pair of dipoles.

Of course, the real problem is how do you match the UHF dipole impedance. To do this an optimizing technique was devised. It consists of a batch file which has NEC-3 to calculate input impedances based on increasing and decreasing the following parameters:

a) Length of UHF dipole
b) Radius of UHF dipole from vertical axis
c) Radius of UHF dipole

The diameter of the VHF dipole was fixed as 2 inches. Table 3-2 provides a listing for the batch file. DNEC1200.EXE is a compiled executable of the NEC-3 Fortran program.

The UHFA.EXE and U.EXE files are compiled files of basic programs that provide input files for the NEC programs. The OPTA.EXE and OPT.EXE are executable files for basic optimizing programs which optimize an AMU for each configuration analyzed by NEC. The optimization process selects the configuration which gives the lowest weighted VSWR over the frequency band and the program looks until no further improvement is achieved by varying the parameters listed above.

Copies of the basic programs are provided in Appendix E.

The optimization program ran and looped about 100 times which meant that NEC ran about 600 times. The computer found an AMU which matched the antenna to a VSWR of less than 2:1. Unfortunately, time and money have run out on the study and we did not get a chance to see if we could get this to work in a prototype antenna.

E-Plane radiation patterns were computed for the UHF antenna. Figures 3-12, 3-13, 3-14 and 3-15 provide the patterns for 225, 300, 390 and 450 MHz. The theoretical gain varies from about 3.5 to about 6 dBi. Would expect this to be reduced on the real antenna. Additional patterns are provided in Appendix F.

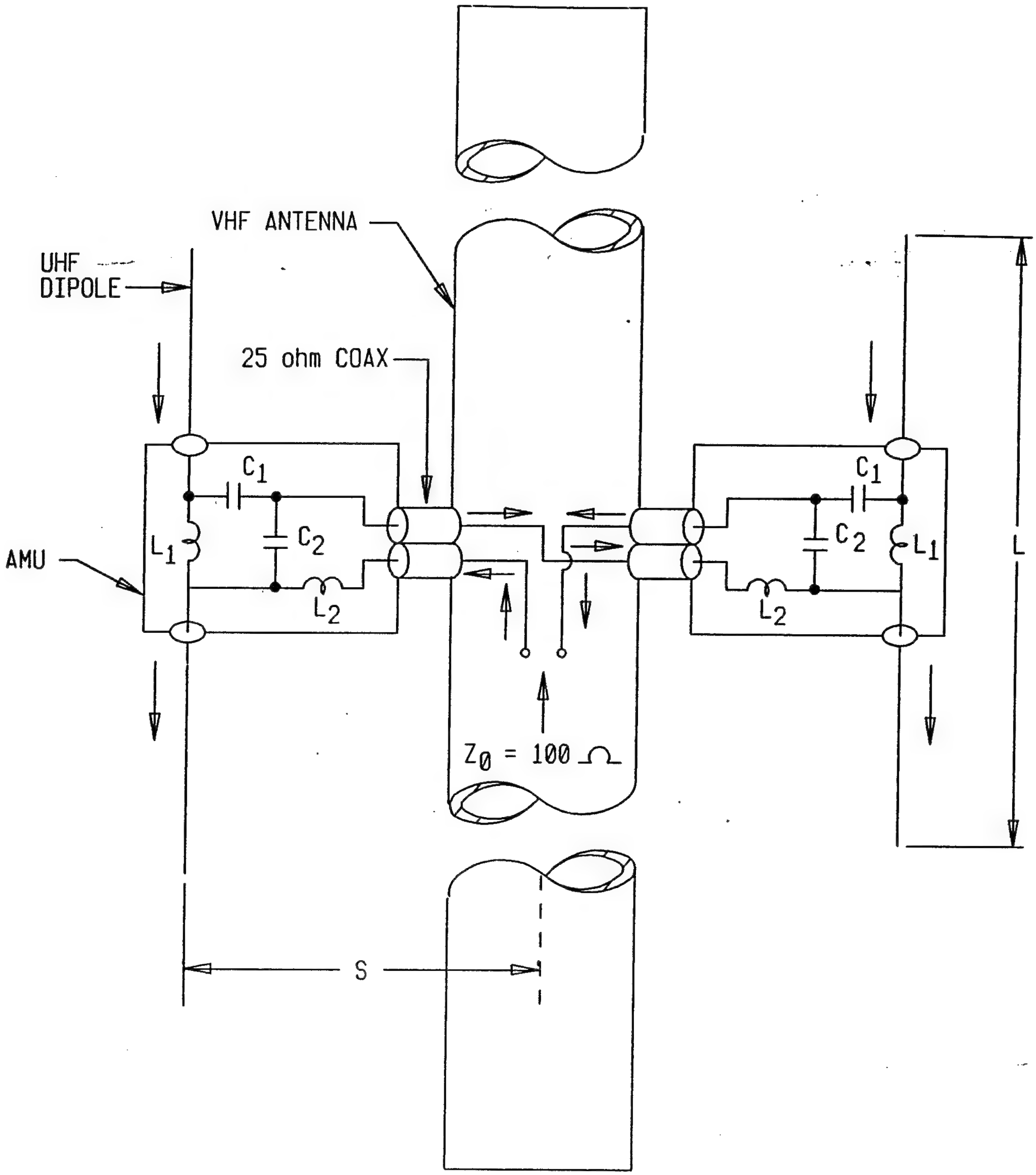
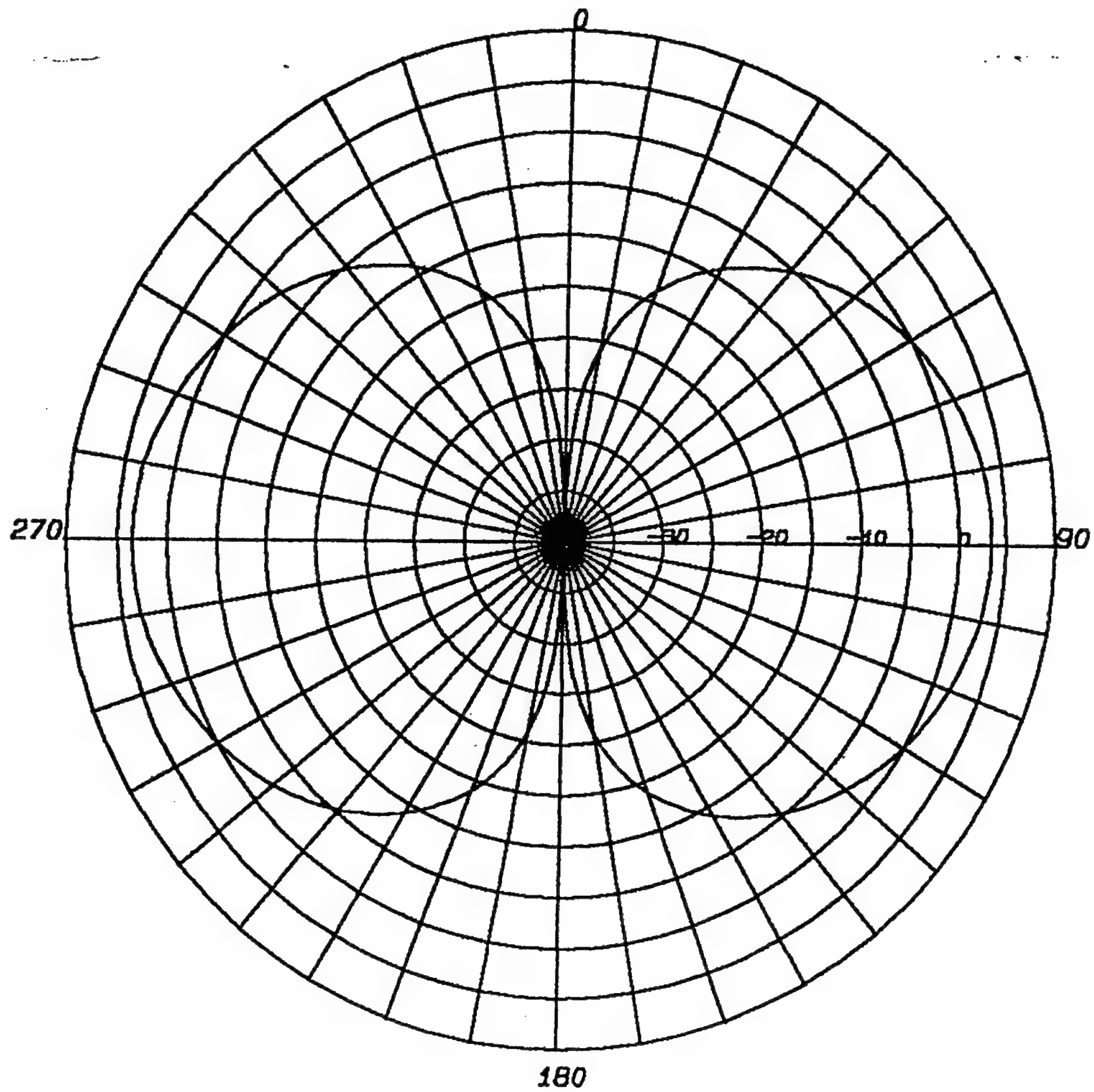


FIGURE 3-11
UHF Feed Network

```
CLS
@ ECHO OFF
IF EXIST P.TXT DEL P.TXT
UHFA
DNEC1200 <U0.COM
OPTA
:LOOP
U
DNEC1200 <U1.COM
DNEC1200 <U2.COM
DNEC1200 <U3.COM
DNEC1200 <U4.COM
DNEC1200 <U5.COM
DNEC1200 <U6.COM
OPT
IF EXIST P.TXT GOTO DONE
GOTO LOOP
:DONE
```

TABLE 3-2
Batch File for Optimizing Antenna Impedance

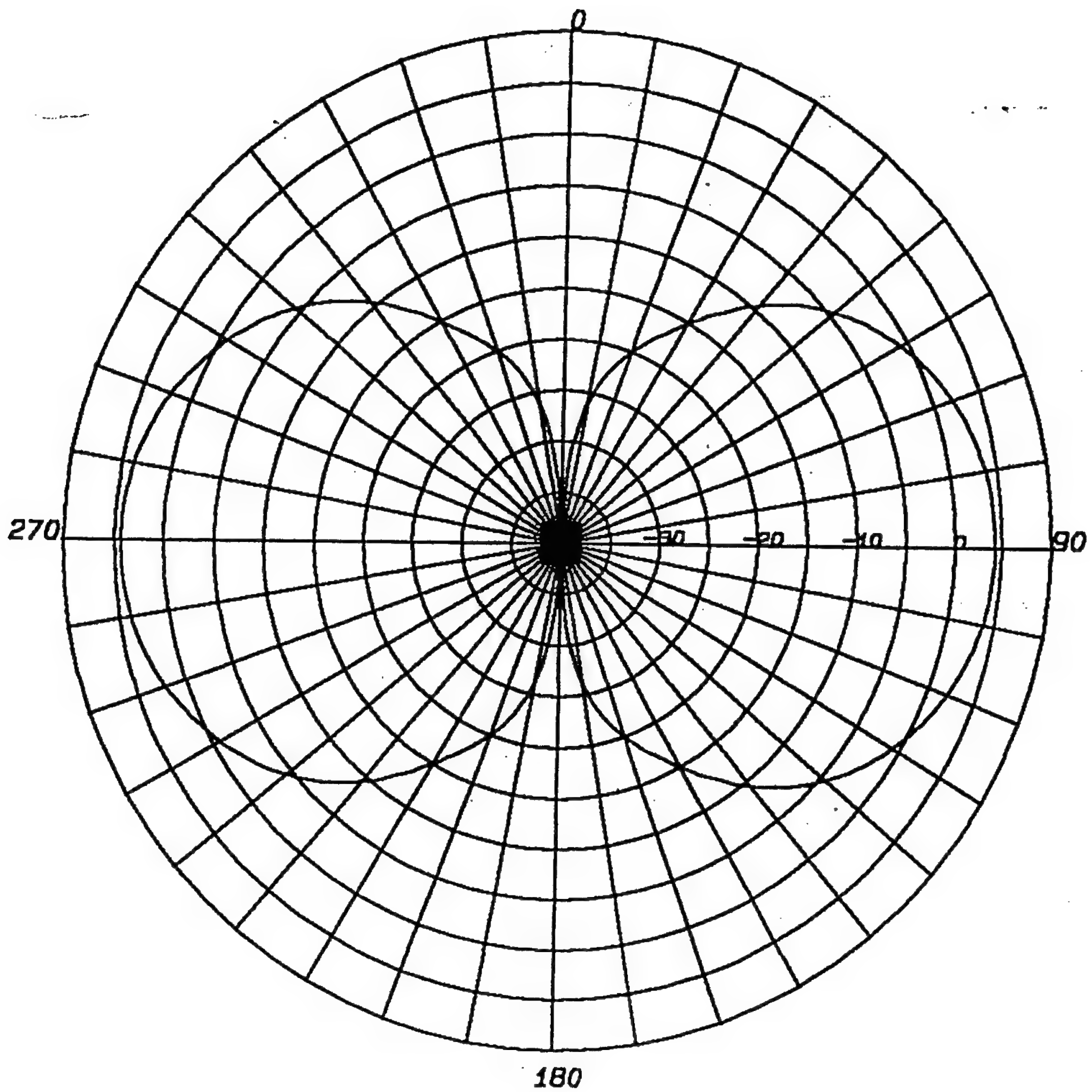
Antenna Products Corp.
Mineral Wells, Texas



Four Dipole UHF Antenna : L = .4M
Frequency = 225 MHz : Scale is dBi
Gain = 3.46 dBi : Theta = 89 Degrees

FIGURE 3-12

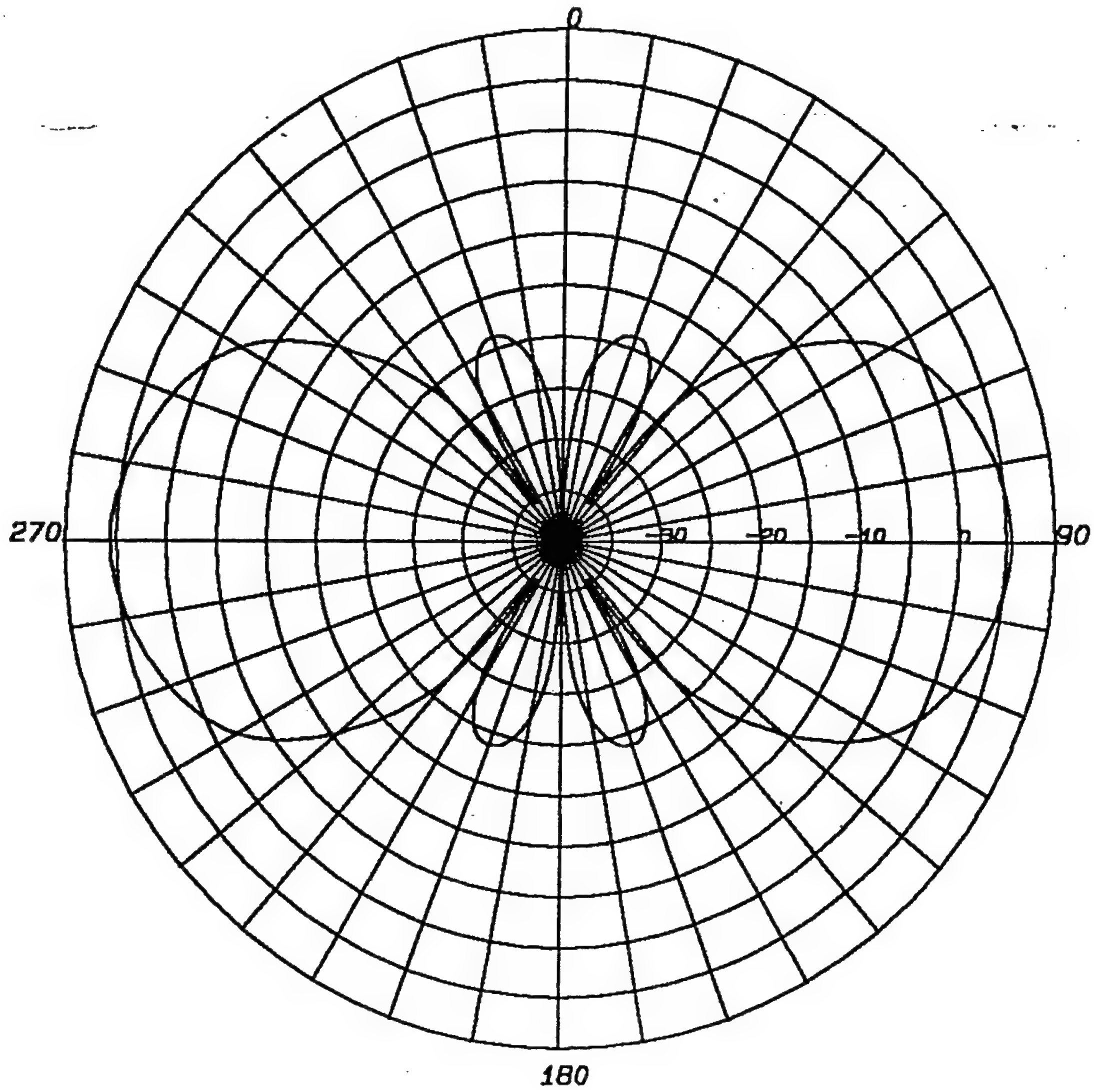
Antenna Products Corp.
Mineral Wells, Texas



Four Dipole UHF Antenna : L = .4M
Frequency = 300 MHz : Scale is dBi
Gain = 4.26 dBi : Theta = 89 Degrees

FIGURE 3-13

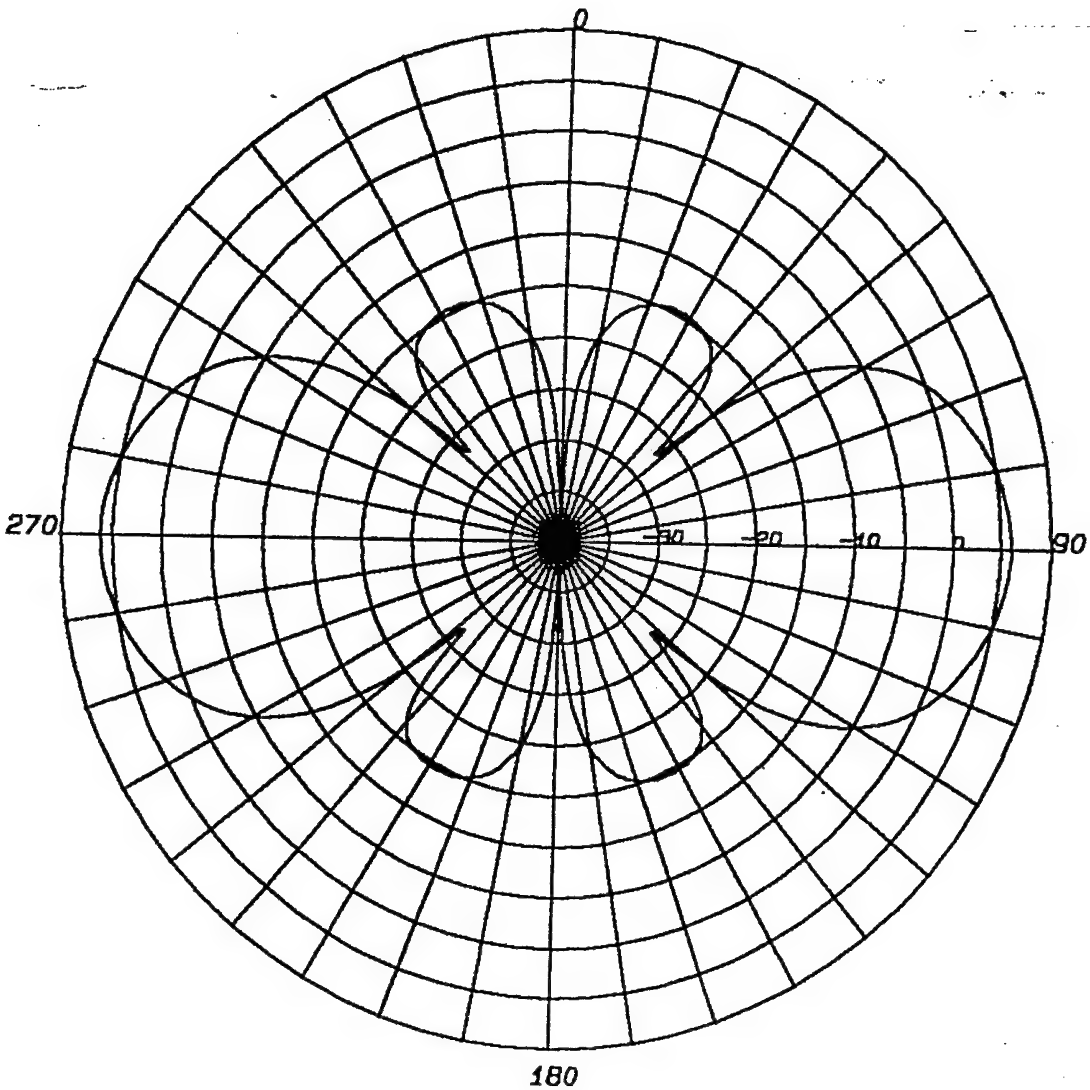
Antenna Products Corp.
Mineral Wells, Texas



Four Dipole UHF Antenna : L = .4M
Frequency = 390 MHz : Scale is dBi
Gain = 5.47 dBi : Theta = 90 Degrees

FIGURE 3-14

Antenna Products Corp.
Mineral Wells, Texas



Four Dipole UHF Antenna : L = .4M
Frequency = 450 MHz : Scale is dBi
Gain = 6.02 dBi : Theta = 90 Degrees

FIGURE 3-15

4.0 CONCLUSION

Configuration A was terminated at the time of the interim report.

Configuration B has been completed and a prototype is installed at the Antenna Products' test site for inspection by CECOM representatives.

The arrangement of configuration C has been altered twice in an effort to achieve a realistic design. The latest concept still has potential for meeting the requirements. More analyses and tests are necessary to pursue this design.

5.0 RECOMMENDATIONS

It is recommended that field tests be conducted on configuration B to determine the range that the antenna can be used for and the suitability of the configuration for its intended use. This may require the design and fabrication of some initial units to be used in the tests. Verification of the range of the surfacewave propagation mode is extremely important.

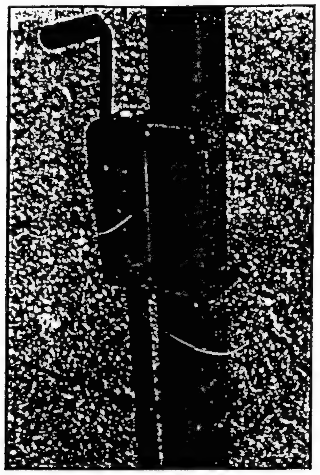
Configuration C is a very complicated design. Initially it was viewed as a monopole within a monopole. After early results the design was changed to a dipole within a dipole. There was too much interaction between dipoles and AMU's in this design. It was then changed to dipoles around dipoles. Early results indicate that this concept has potential; however, time and financing has been expended on this program. Therefore, it is proposed that a new study be funded which would permit further investigation of this concept.

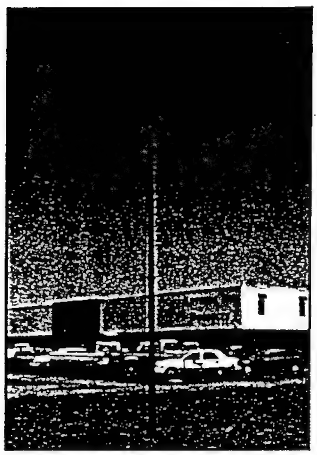
APPENDIX A

Data Sheets for
MAC-Crank Up Masts
MAC – Push-Up Masts

MAC-06/07/C

- LIGHTWEIGHT COMPOSITE MAST
- COMPACT ONE-PERSON CARRY
- RAPID ERECT WITH UNIQUE LOCKING SYSTEM





Applications

The MAC-06/07C composite telescoping mast is a family of lightweight rapid erect masts utilized for elevating transportable antennas from 6 to 10 meter heights. The mast is capable of being shelter mounted unguyed, or ground mounted guyed. The lightweight mast is designed for a one person carry making it ideally suited for use in transportable or tactical applications.

Features

The MAC-06/07C mast is lightweight and compact, utilizing the latest carbon composite materials. This material has several advantages over standard metal masts, such as its strength-to-weight ratio and resistance to corrosive environments. It has a unique drive and mast section locking system which enables the operator to utilize mechanical advantage to safely erect the mast. The mechanically aided mast drive system is a hybrid launcher and cable drive design. Each mast section is internally driven to its locked erected position by the launcher cable drive. The drive system is internal and contained within the center of the bottom mast section. The design incorporates positive drive and retract, and a fail safe mast section locking feature. The mast is erectable from its stowed position to a maximum height of 6 to 10 meters with the flexibility to stop and set the mast at any desired height between the retract and erected height. The mast may also be manually erected by pushing up each section. The mast unit with its drive system is all self contained in one package. Vertical alignment is facilitated by an integral bubble level. The mast is protected under Patent # 5218375.

ANTENNA PRODUCTS

Mast	Height				Weight (lbs)		Deployment Time (minutes)	
Type No.	Extended		Retracted		Mast	Accessories	2 Persons	1 Person
	m	ft	m	ft				
MAC-06/07C	6	19.7	1.29	4.25	34	20	5	7
MAC-07/07C	7	22.97	1.44	4.72	36	21	5.5	8
MAC-08/07C	8	26.25	1.58	5.18	38	21	6	9
MAC-09/07C	9	29.53	1.73	5.67	40	22	6.5	10.5
MAC-10/07C	10	32.81	1.87	6.14	42	22	7	12

Head Load	30 lbs and 2.0 sq ft sail area	Humidity	MIL-STD-810D, Method 507.2 10 cycles, Proc. III
Wind			
Operational		Fungus	MIL-STD-810D, Method 508.2
Guyed	60 mph with 0.5 inch of ice	Salt Fog	MIL-STD-810D, Method 509.2
Unguyed	25 mph without ice	Sand and Dust	MIL-STD-810D, Method 510.2
Survival	80 mph with 0.5 inch of ice	Vibration/Shock	MIL-STD-810D, Method 514.3
Altitude		Finish	CARC
Operation	10,000 ft	Leveling	Ability to accomodate sloped terrain up to 10° slope
Transport	40,000 ft		
Temperature			
Operating	-50°F to +120°F plus solar radiation		
Storage	-60°F to +155°F		

MAC-06/07/P

- LIGHTWEIGHT COMPOSITE MAST
- COMPACT ONE-PERSON CARRY
- RAPID ERECT WITH UNIQUE LOCKING SYSTEM

Applications

The MAC-06/07P composite telescoping mast is a push-up lightweight rapid erect mast utilized for elevating transportable antennas from 6 to 10 meter heights. The mast is capable of being shelter mounted unguyed, or ground mounted guyed. The lightweight mast is designed for a one person carry making it ideally suited for use in highly transportable tactical applications.

Features

The MAC-06/07P push-up mast is lightweight and compact, utilizing the latest carbon composite materials. This material has several advantages over standard metal masts, such as its strength-to-weight ratio and resistance to corrosive environments. The mast consists of seven (7) square with rounded comer, carbon fiber composite, telescoping tube sections. In the stowed position, all sections are interlocked to prevent inadvertent extension. To extend the mast to the desired height, a section is unlocked and extended. The mast sections automatically locks at any desired level between the retracted and extended height. The automatic locking feature prevents unintentional retraction of the mast. The locking feature, provided by a toggle clamping vise, provides increased clamping action with increased down load. Vertical alignment is facilitated by an integral bubble level. The mast is protected under Patent # 5218375.

ANTENNA PRODUCTS

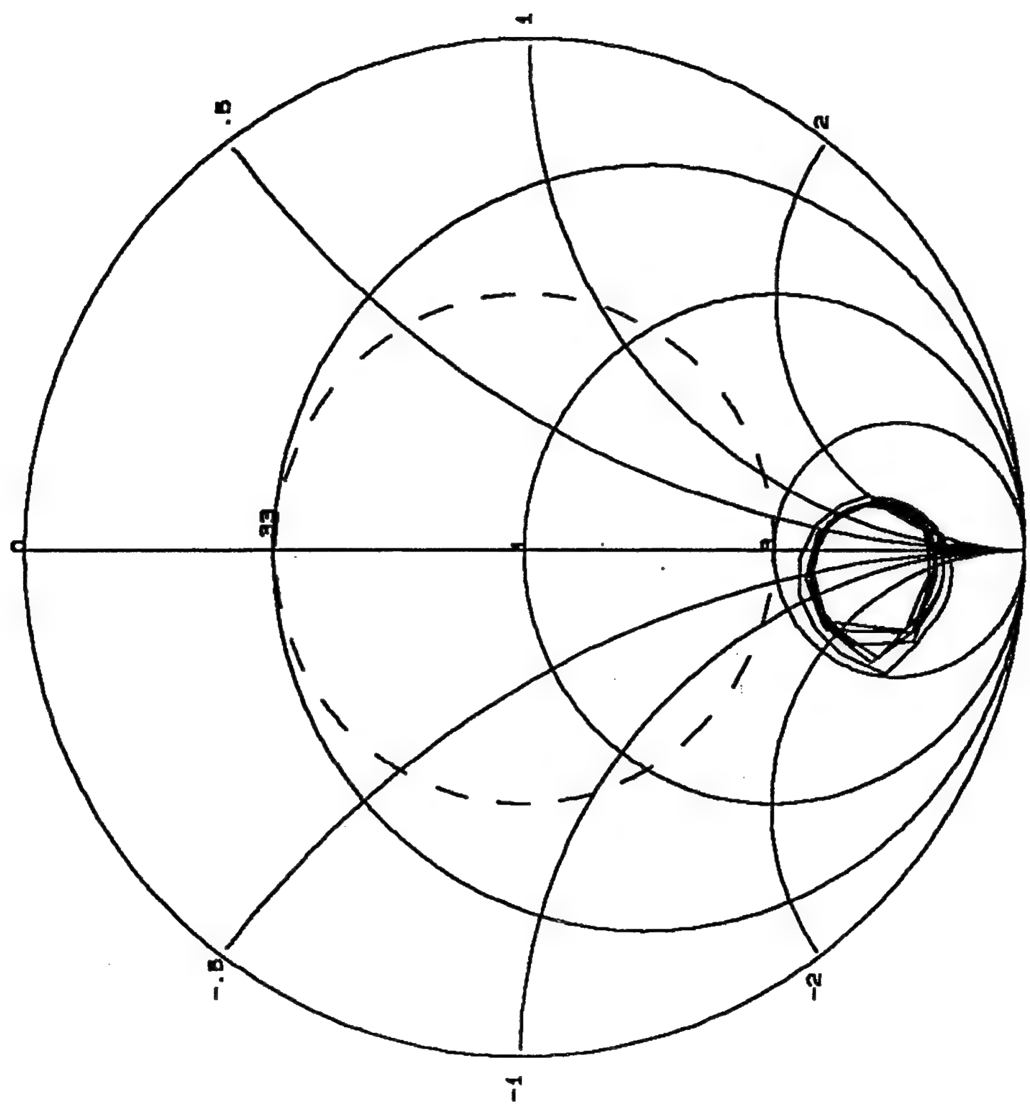
MAC-06/07/P Deployed

Mast Type No.	Height Extended m	Height Extended ft	Height Retracted m	Height Retracted ft	Weight (lbs) Mast	Weight (lbs) Accessories	Deployment Time (minutes) 2 Persons	Deployment Time (minutes) 1 Person
MAC-06/07P	6	19.7	1.29	4.25	34	20	5	7
MAC-07/07P	7	22.97	1.44	4.72	36	21	5.5	8
MAC-08/07P	8	26.25	1.58	5.18	38	21	6	9
MAC-09/07P	9	29.53	1.73	5.67	40	22	6.5	10.5
MAC-10/07P	10	32.81	1.87	6.14	42	22	7	12

Head Load	30 lbs and 2 sq ft sail area	Humidity	MIL-STD-810D, Method 507.2 10 cycles, Proc. III
Wind		Fungus	MIL-STD-810D, Method 508.2
Operational		Salt Fog	MIL-STD-810D, Method 509.2
Guyed	60 mph with 0.5 inch of ice	Sand and Dust	MIL-STD-810D, Method 510.2
Unguyed	25 mph without ice	Vibration/Shock	MIL-STD-810D, Method 514.3
Survival	80 mph with 0.5 inch of ice	Finish	CARC
Altitude		Leveling	Ability to accomodate sloped terrain up to 10° slope
Operation	10,000 ft		
Transport	40,000 ft		
Temperature			
Operating	-50°F to +120°F plus solar radiation		
Storage	-60°F to +155°F		

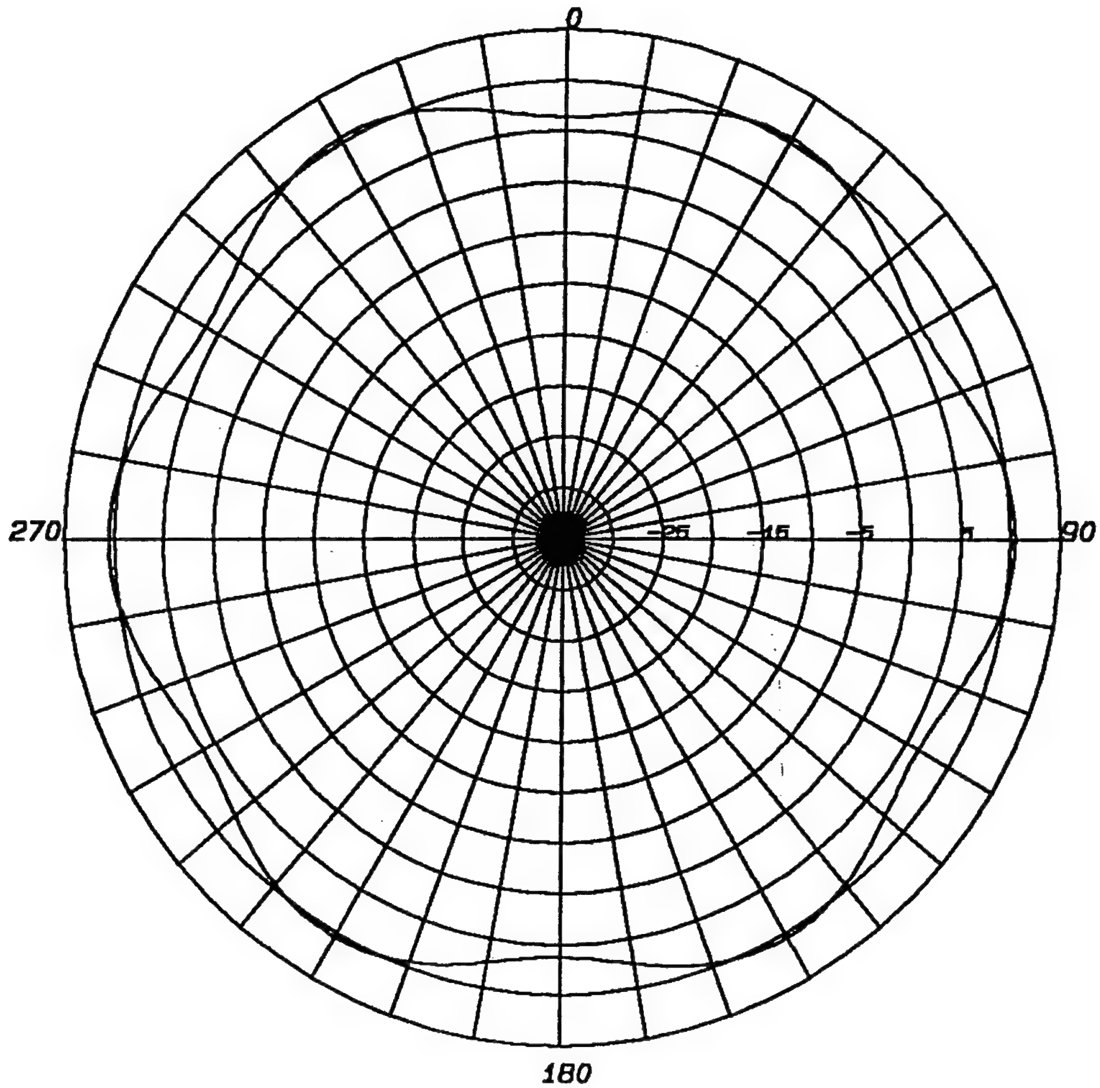
APPENDIX B

Impedances and Radiation Patterns For Sets of Wires Being Insulated at Top of Masts



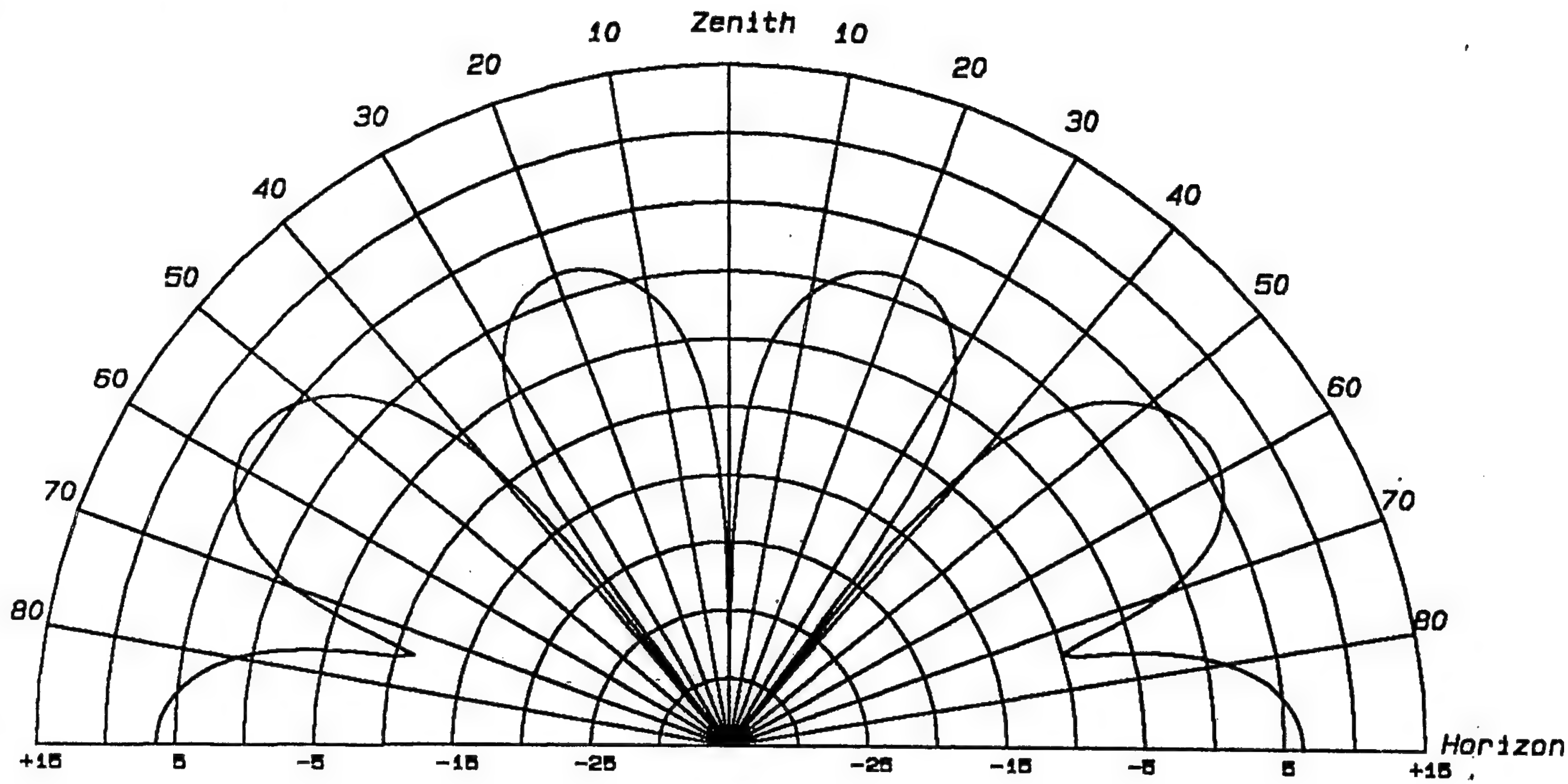
Three Rhombic Antenna Array
Six Feed Array : No Mast : L = 10 M
Impedance = 50 Ohms : 02-25-1998

Antenna Products Corp.
Mineral Wells, Texas



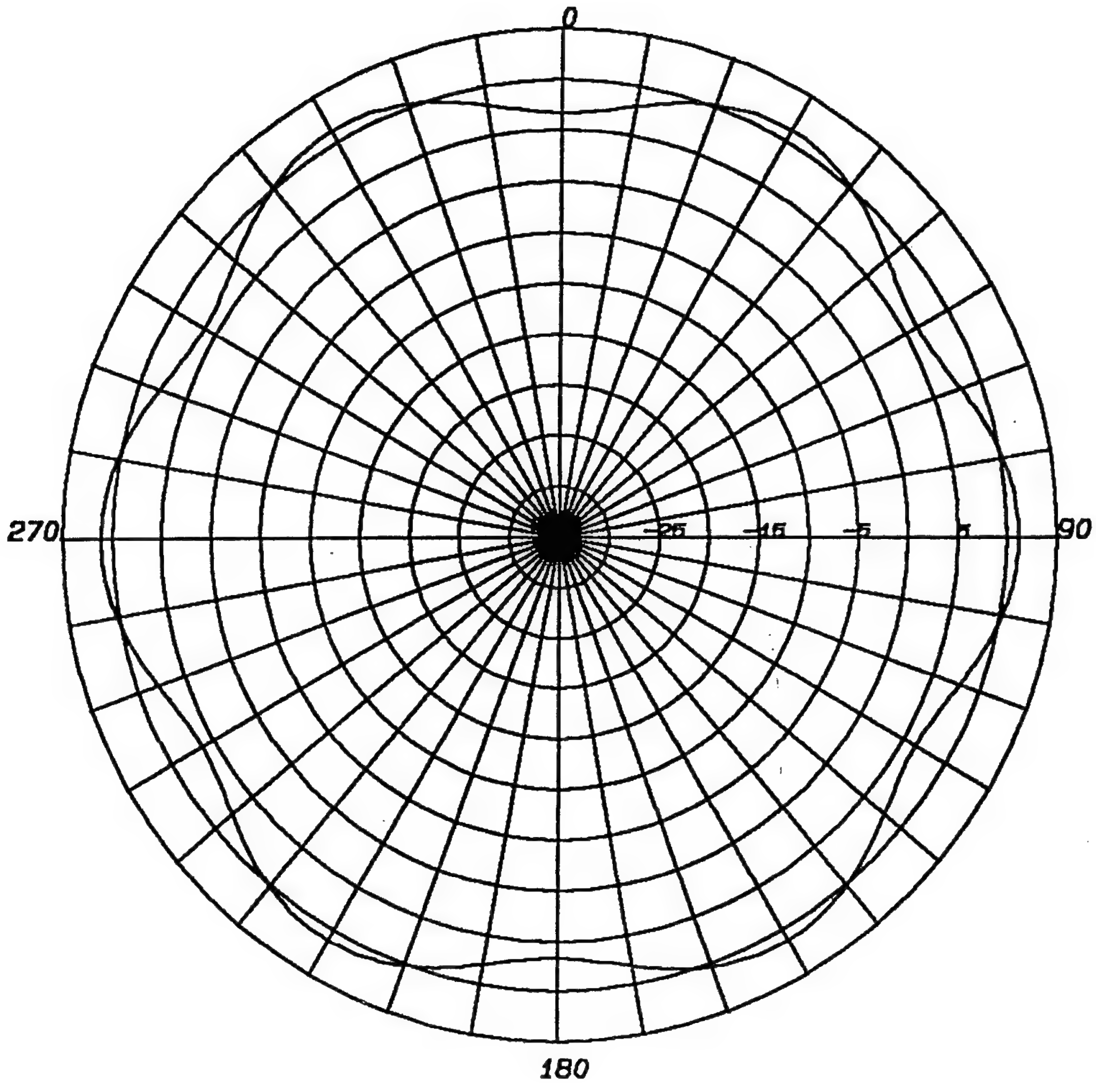
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 30 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



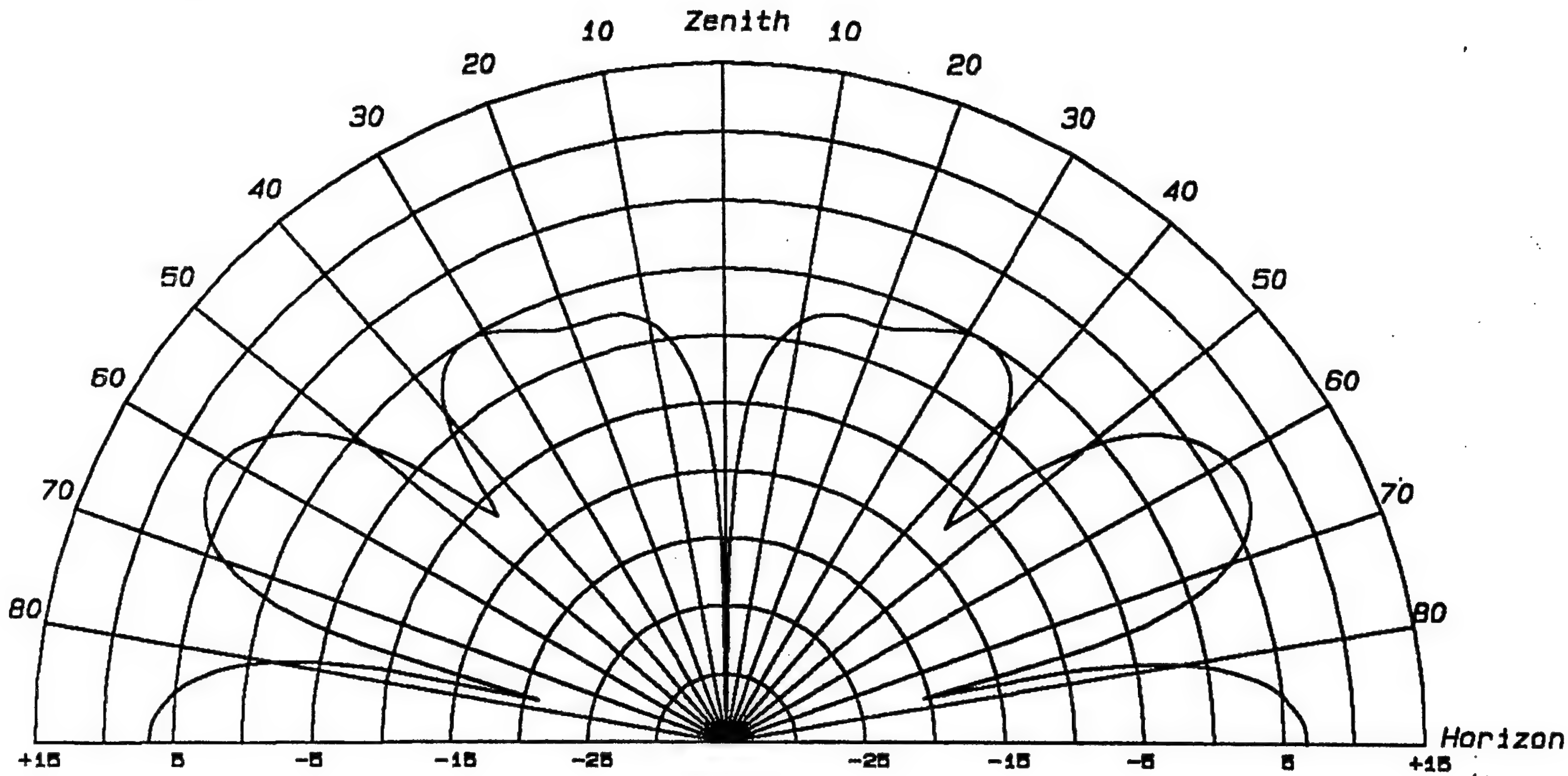
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 30 MHz : Dielectric Mast
Gain = 6.41 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



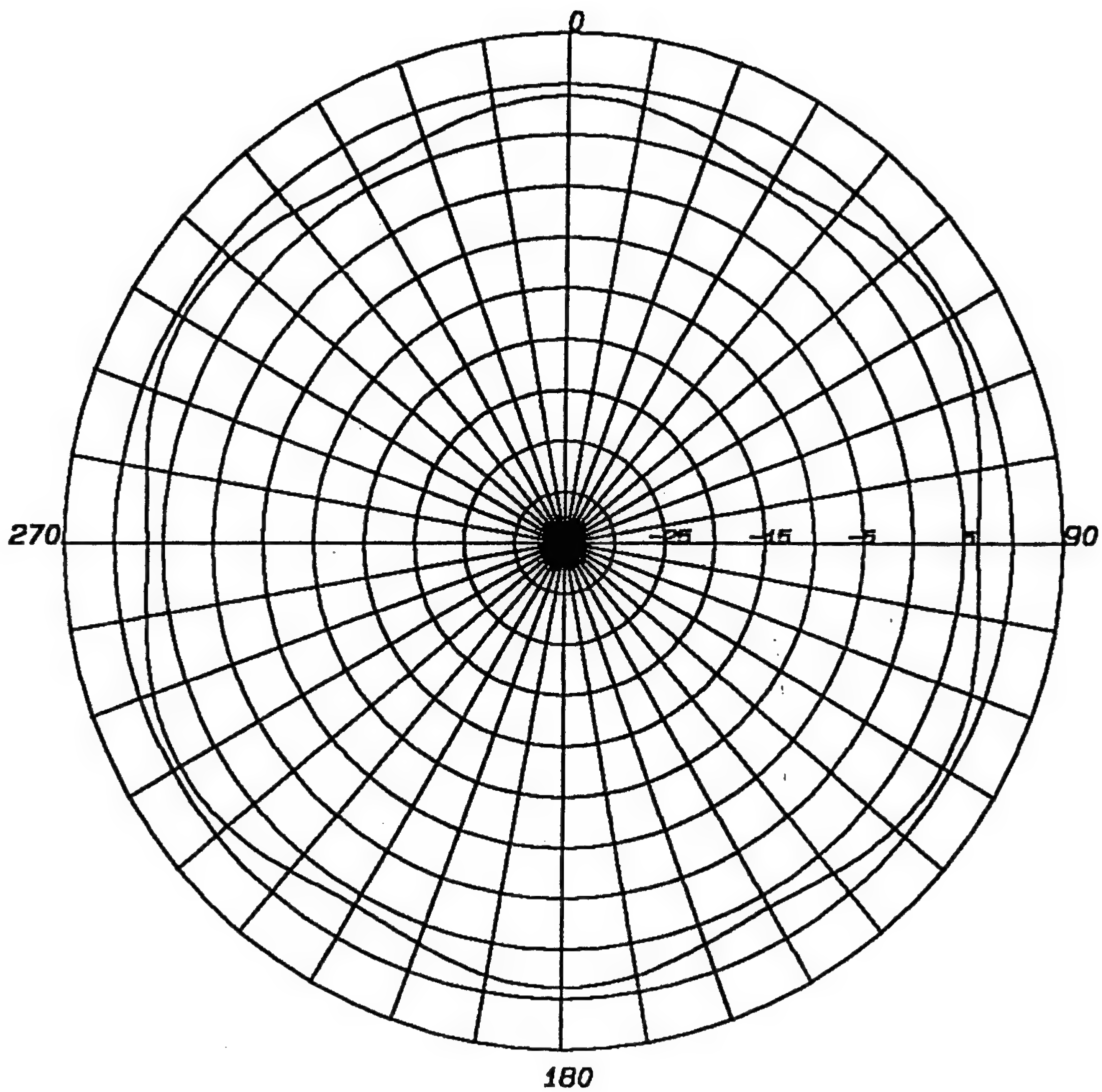
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 35 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



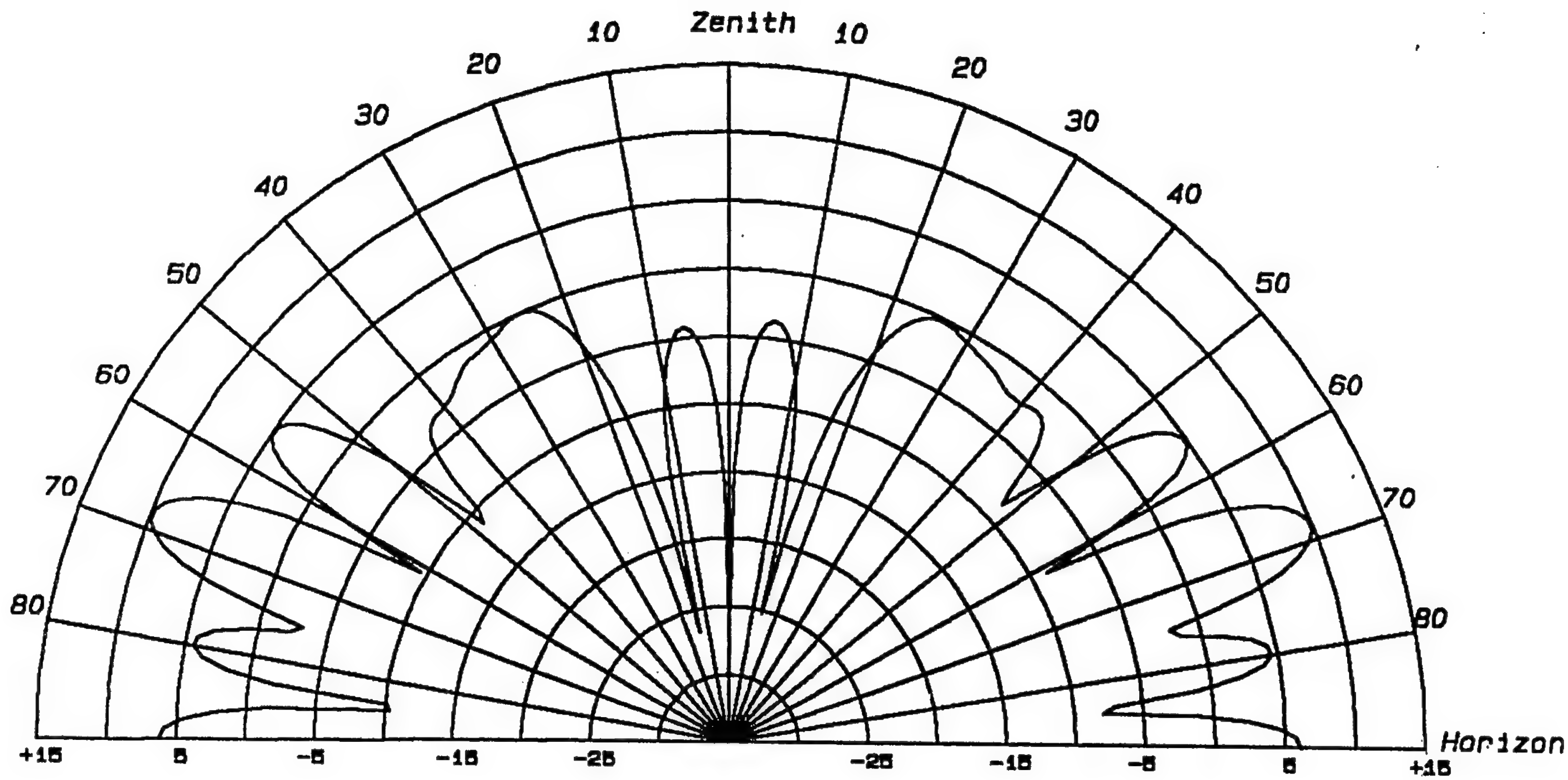
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 35 MHz : Dielectric Mast
Gain = 6.91 dBi : Theta = 62 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



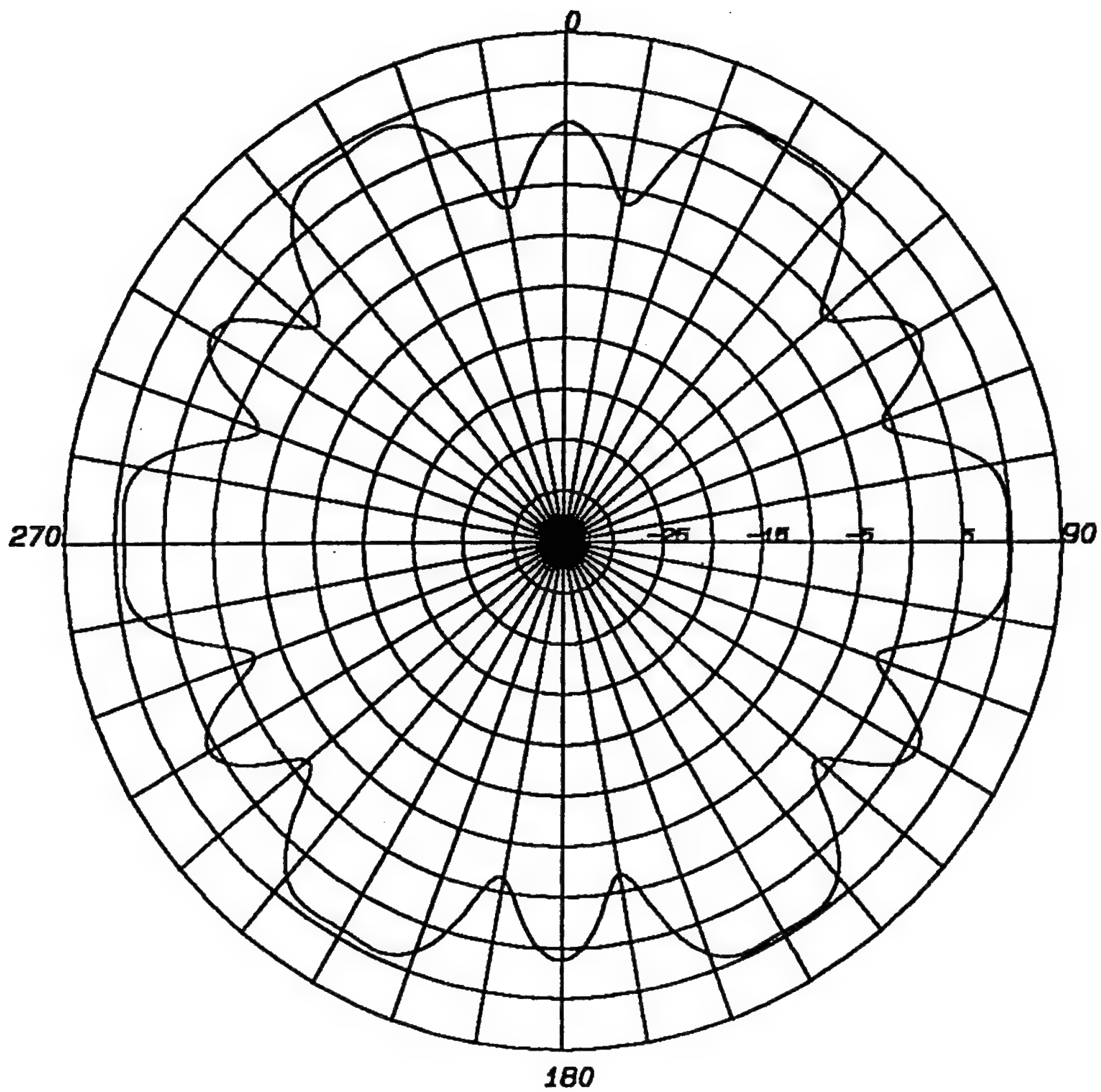
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 40 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



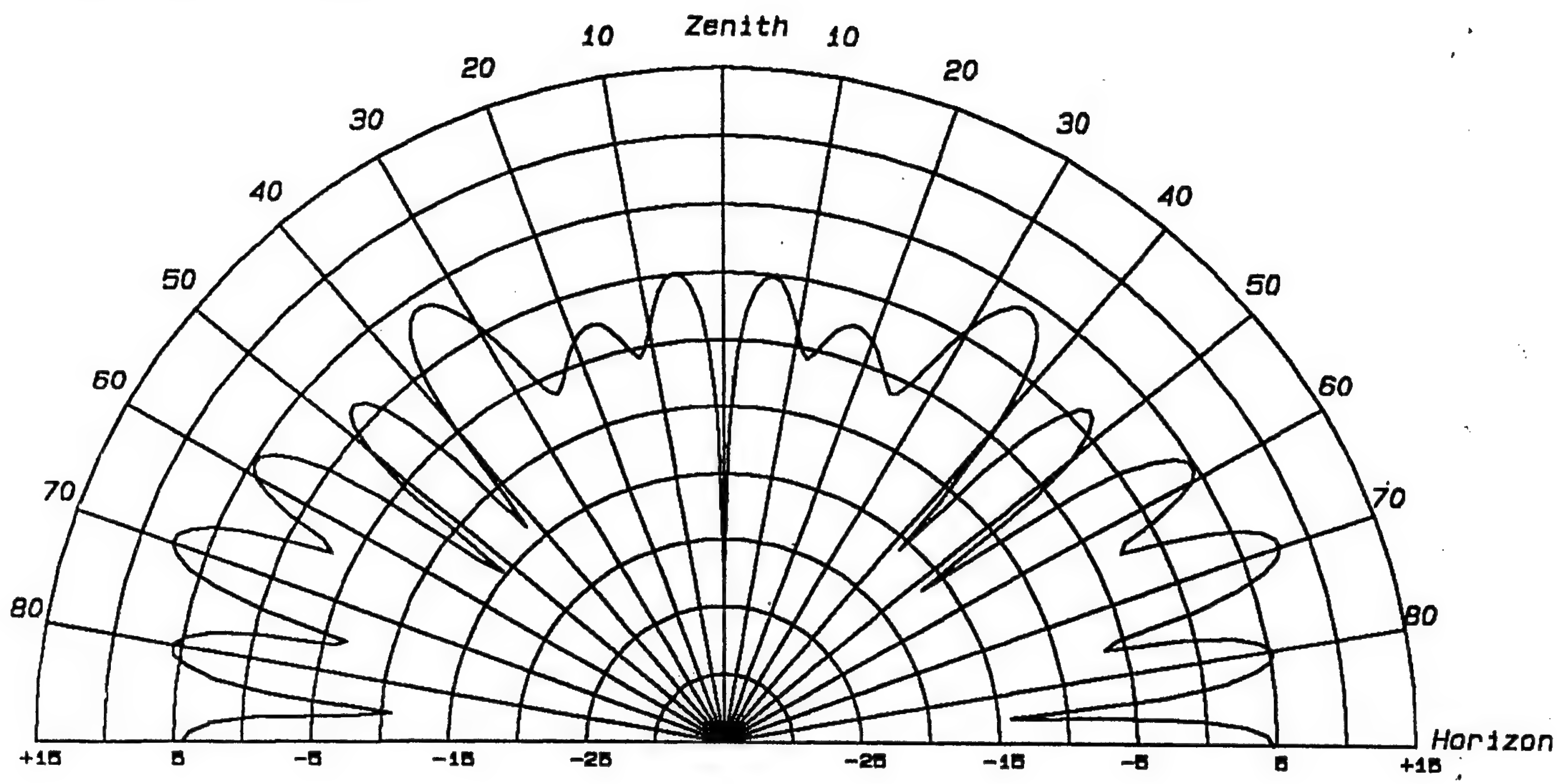
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 85 MHz : Dielectric Mast
Gain = 9.85 dBi : Theta = 68 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



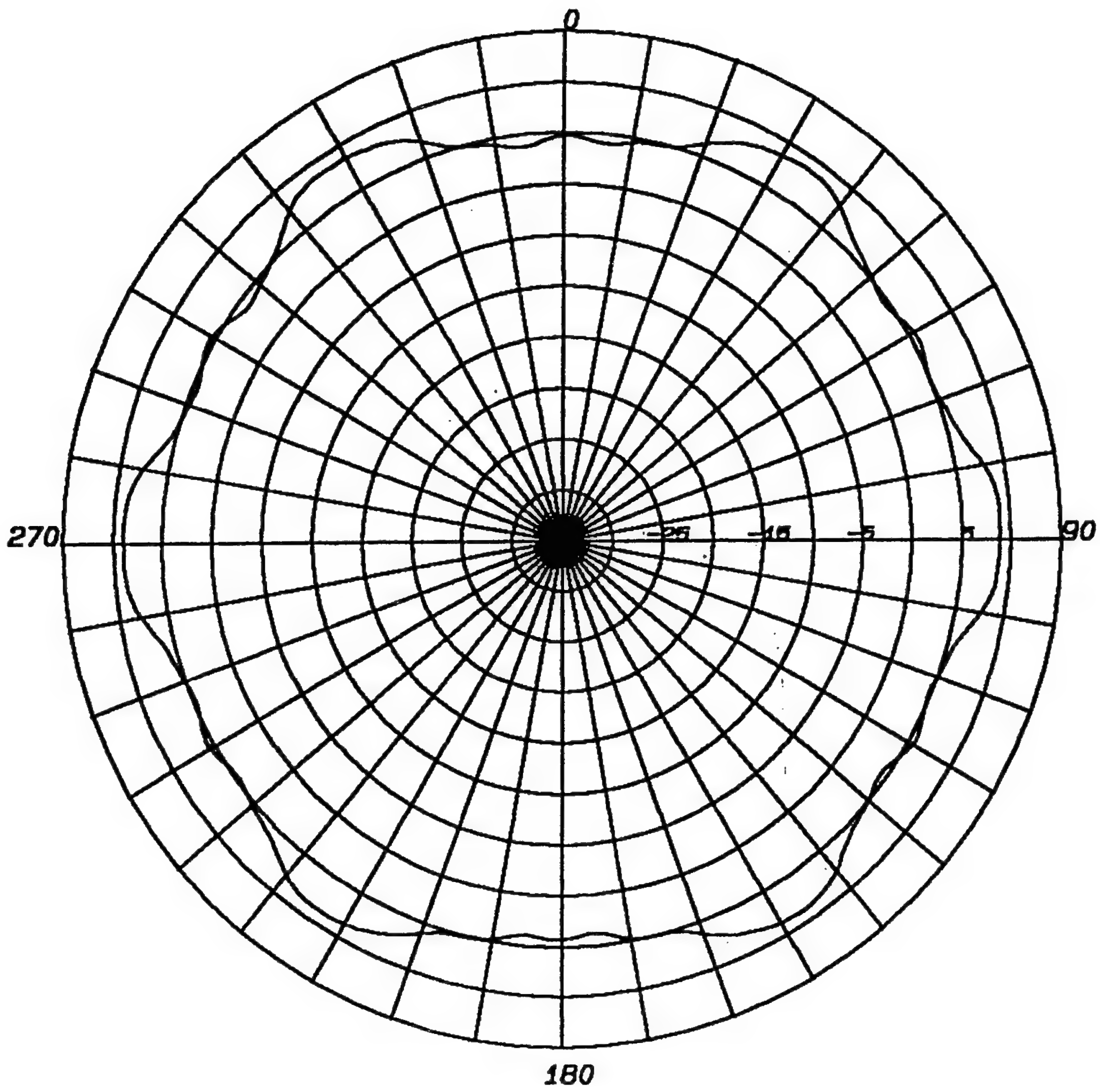
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 85 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



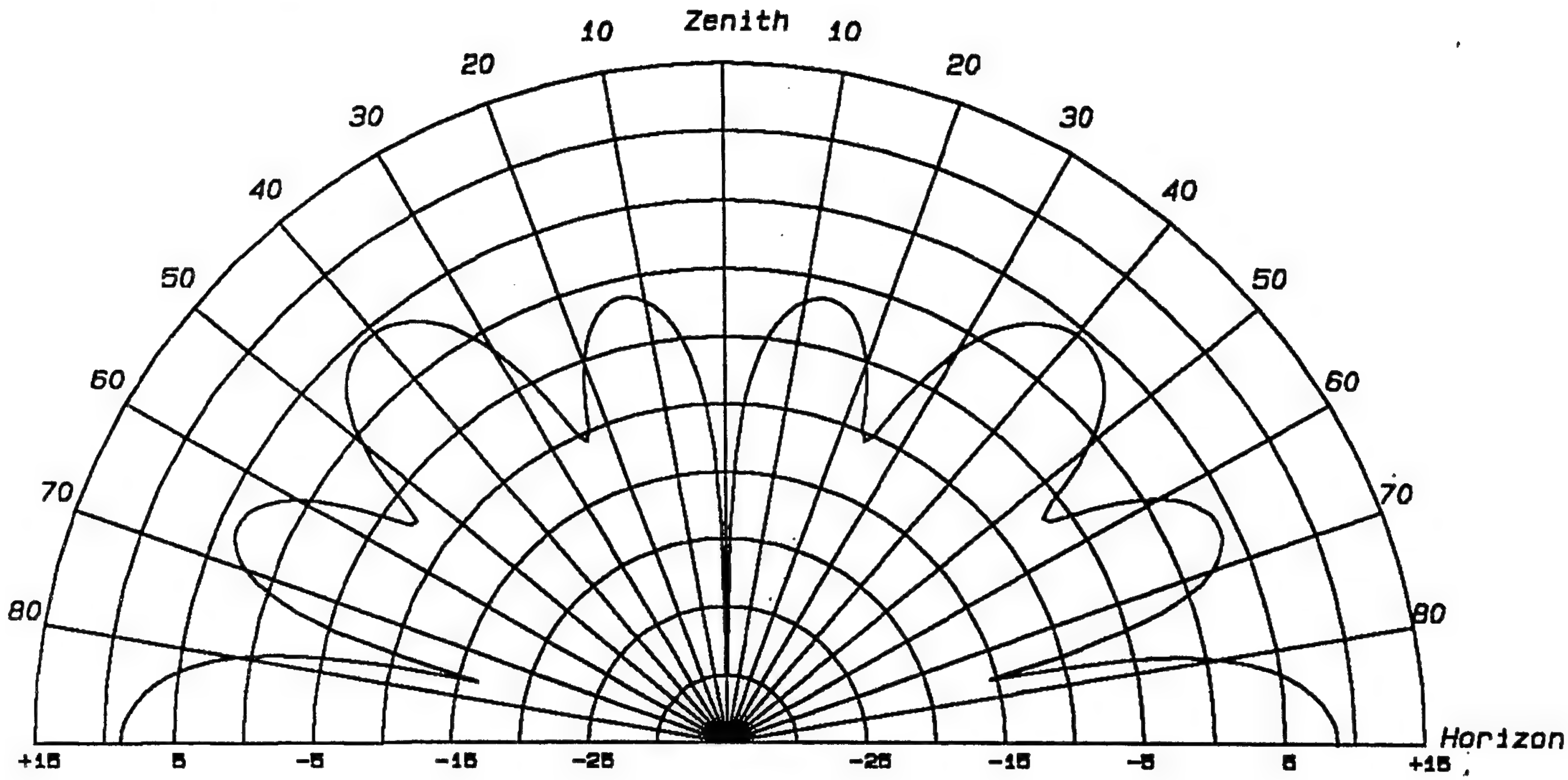
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 90 MHz : Dielectric Mast
Gain = 7.78 dBi : Theta = 70 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



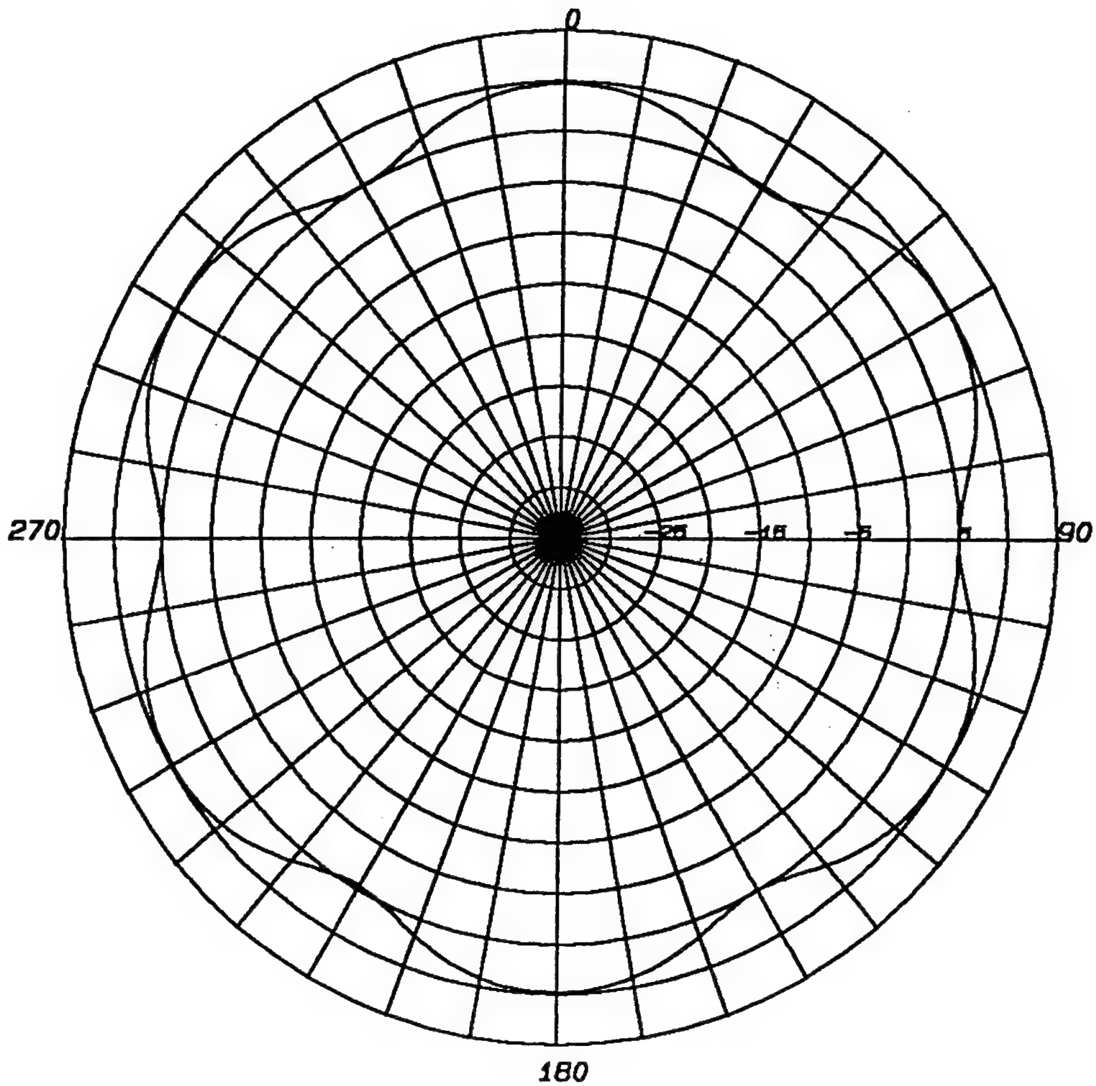
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 90 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



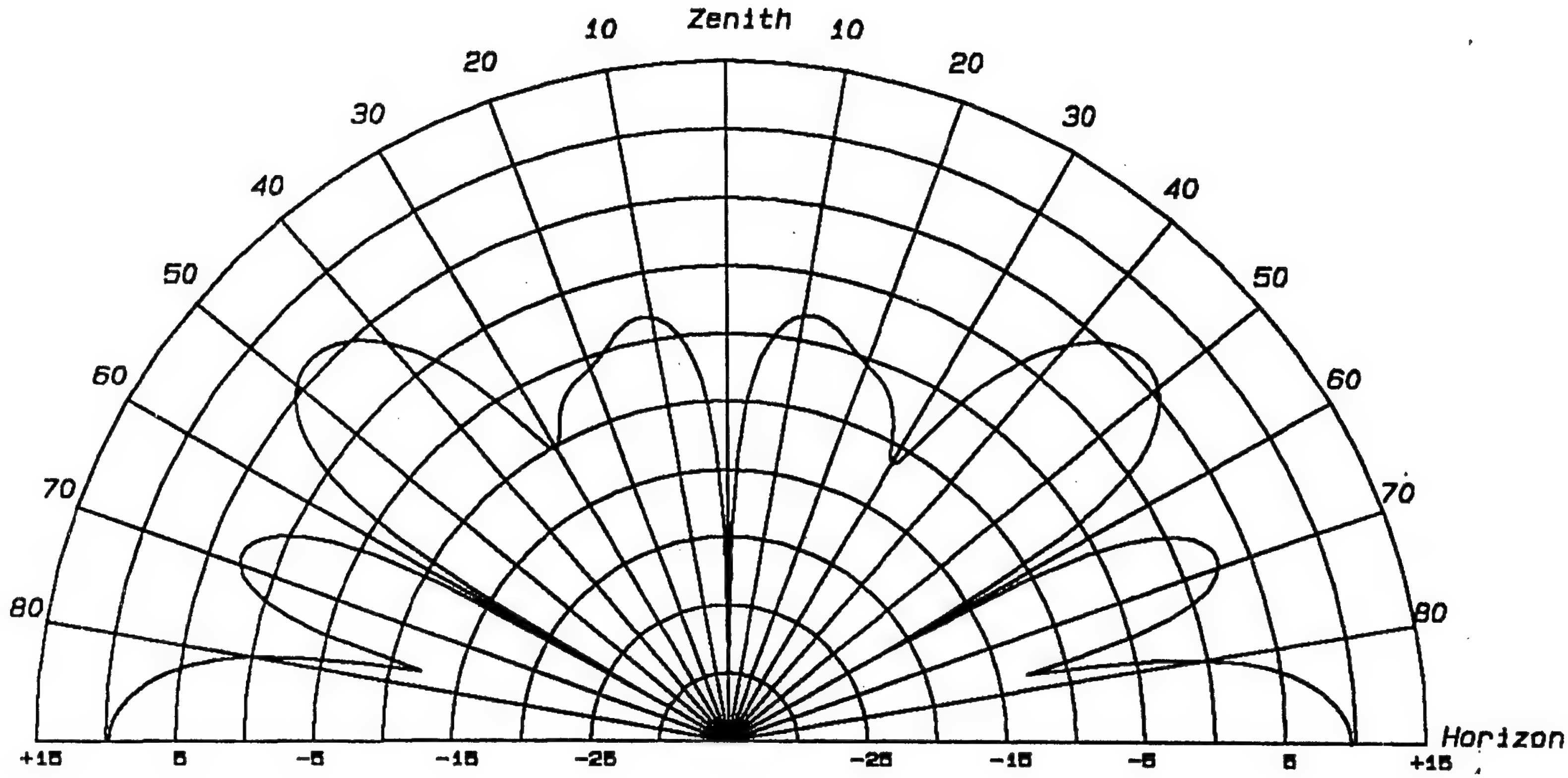
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 40 MHz : Dielectric Mast
Gain = 8.81 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



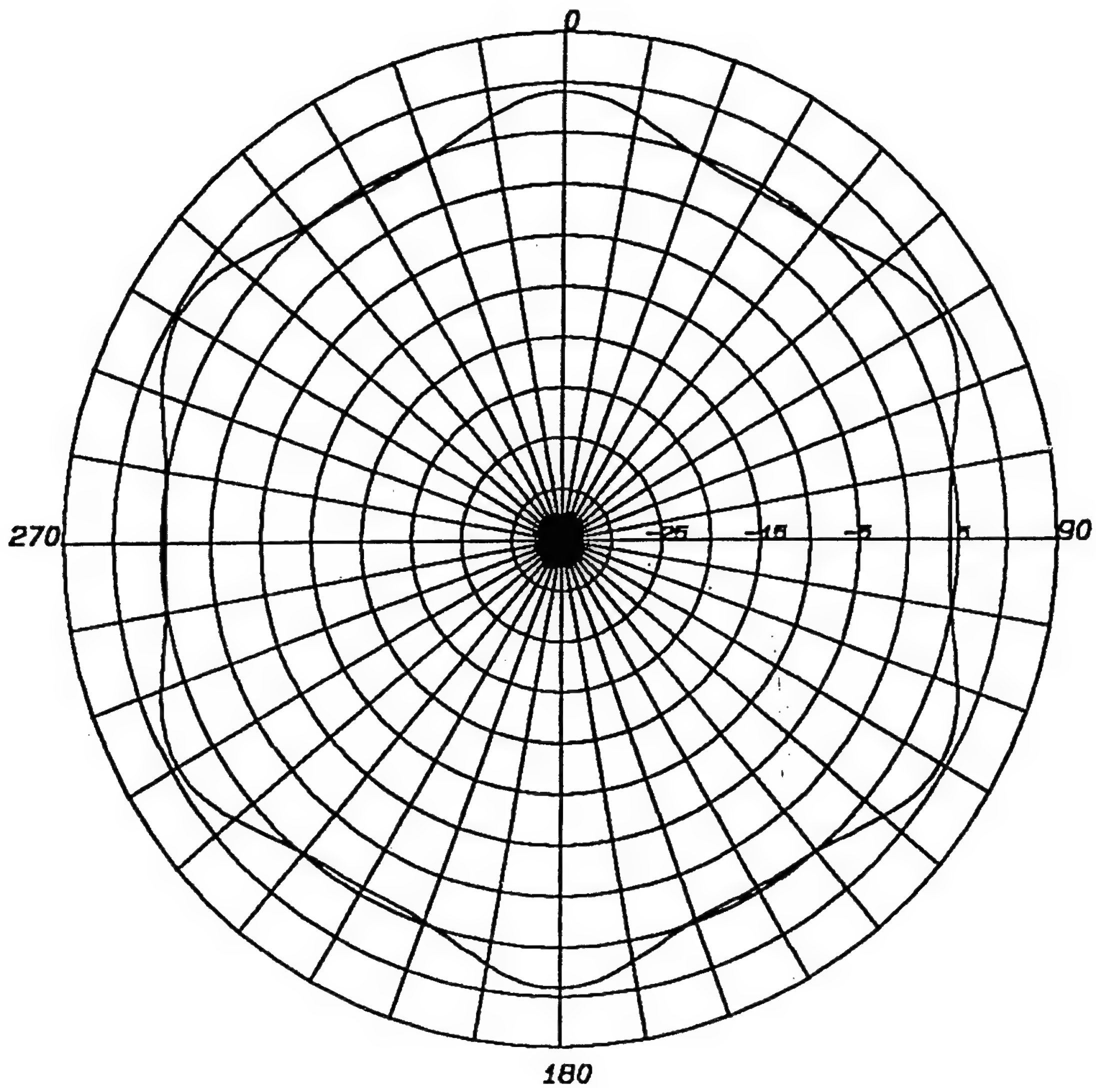
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 45 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



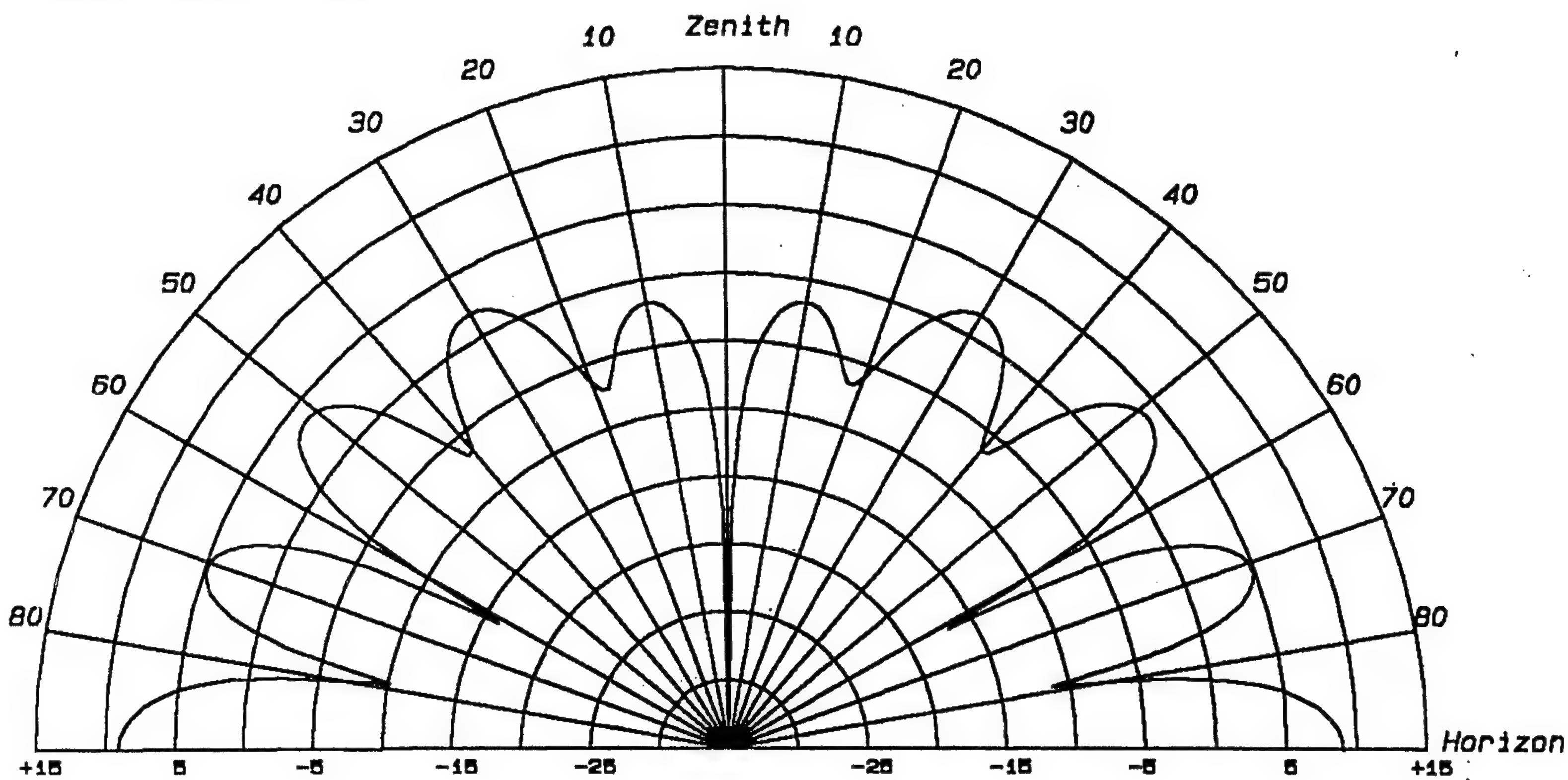
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 45 MHz : Dielectric Mast
Gain = 9.73 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



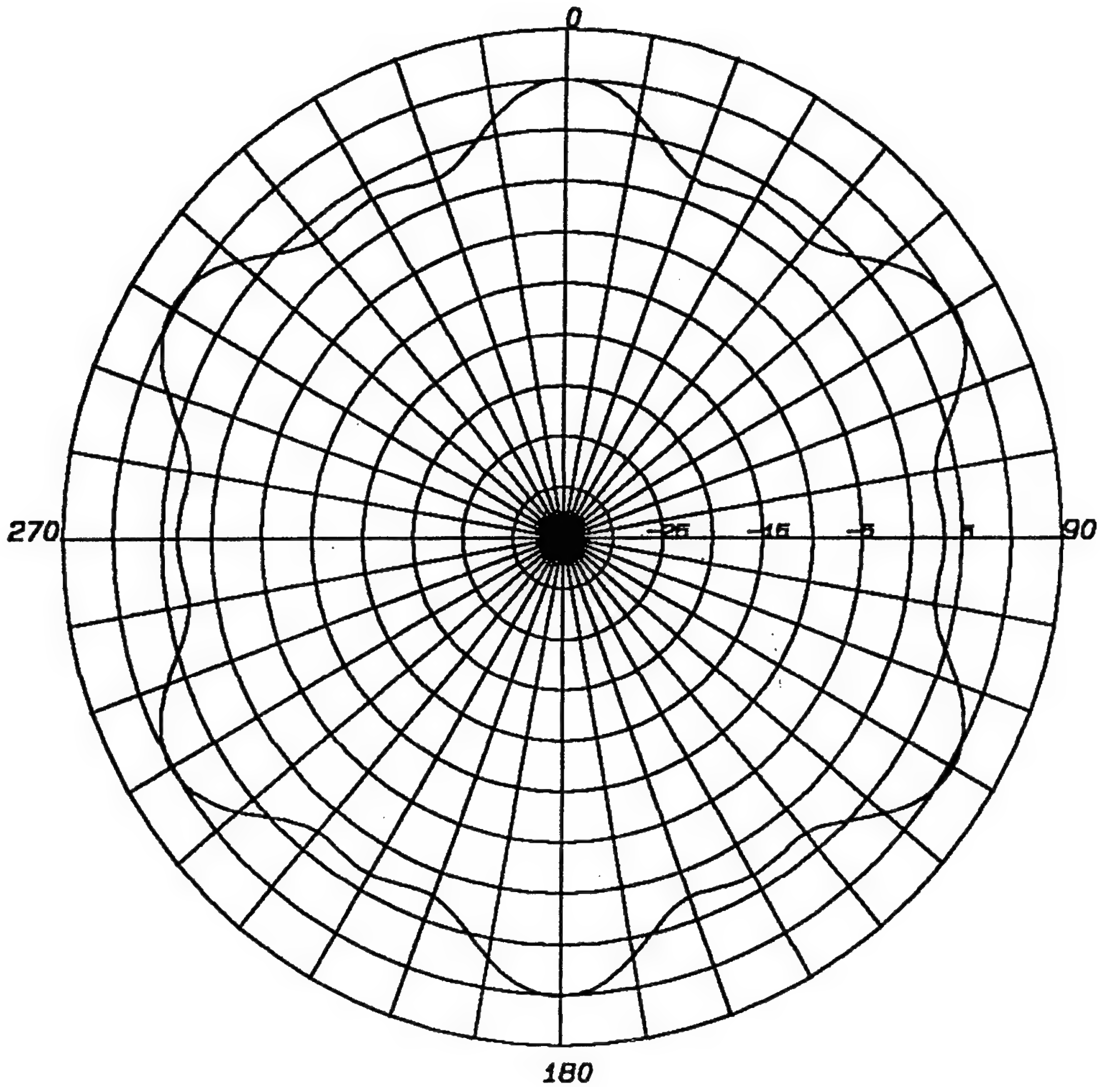
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 50 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



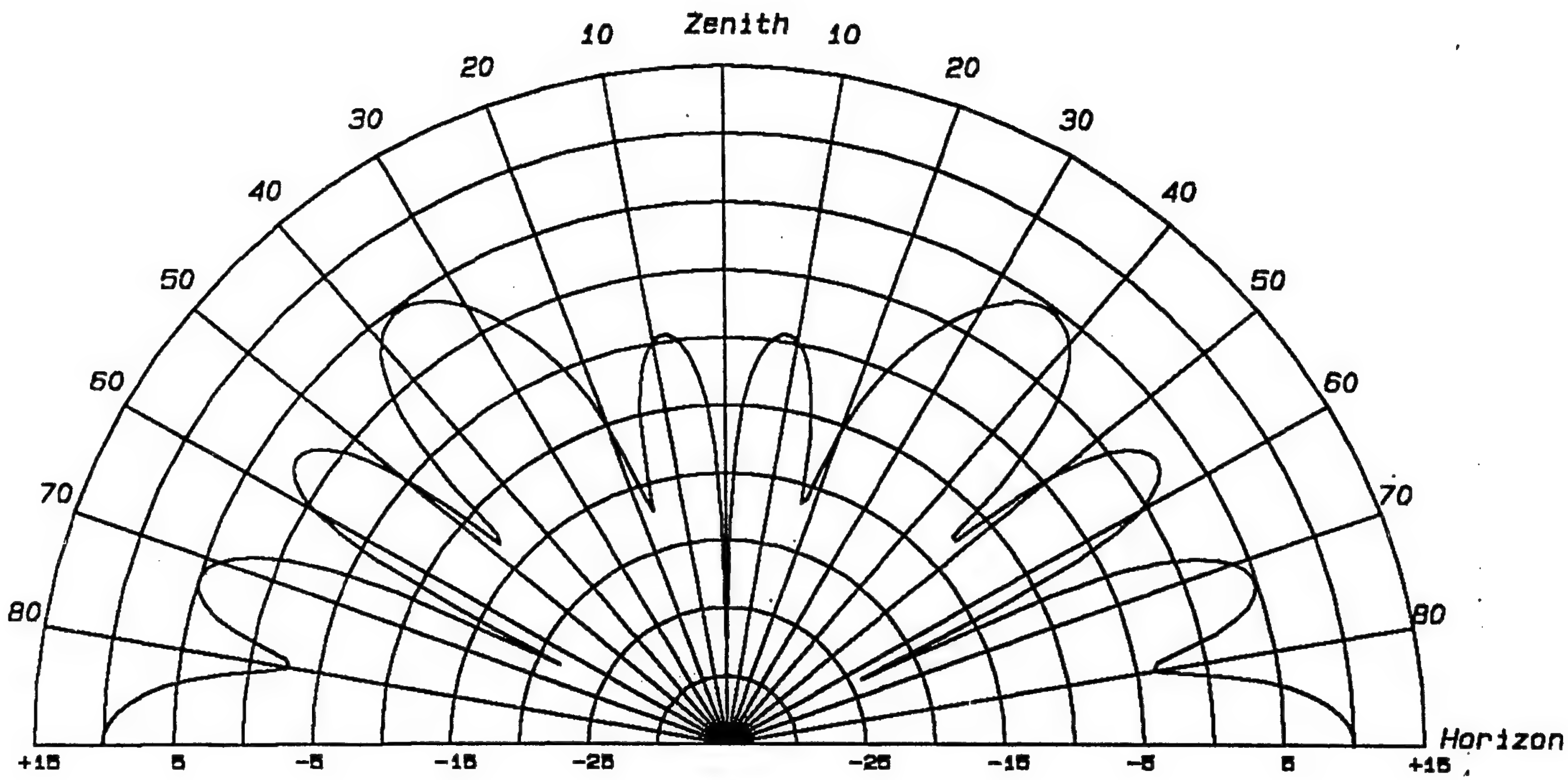
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 50 MHz : Dielectric Mast
Gain = 9.07 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



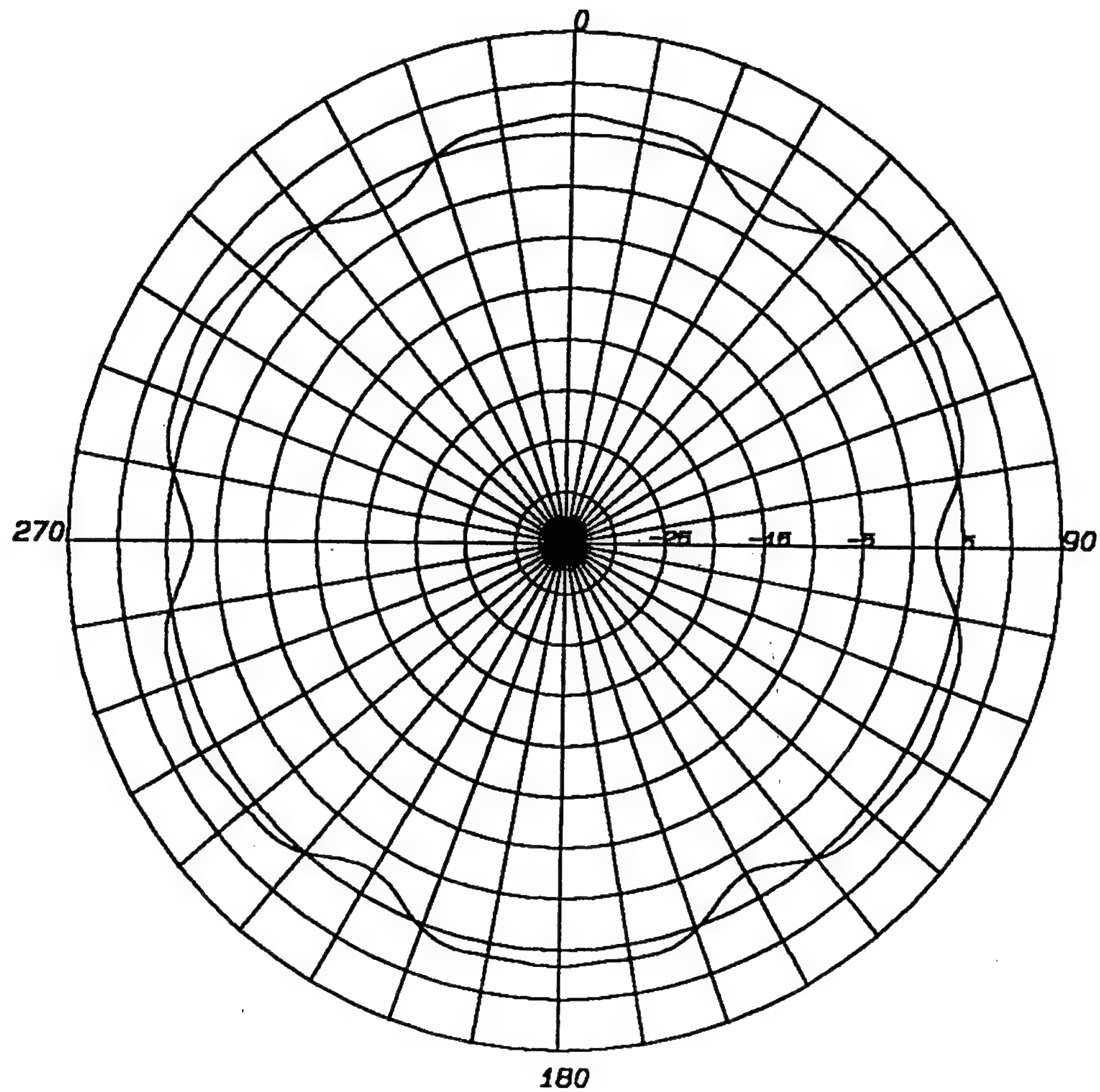
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 55 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



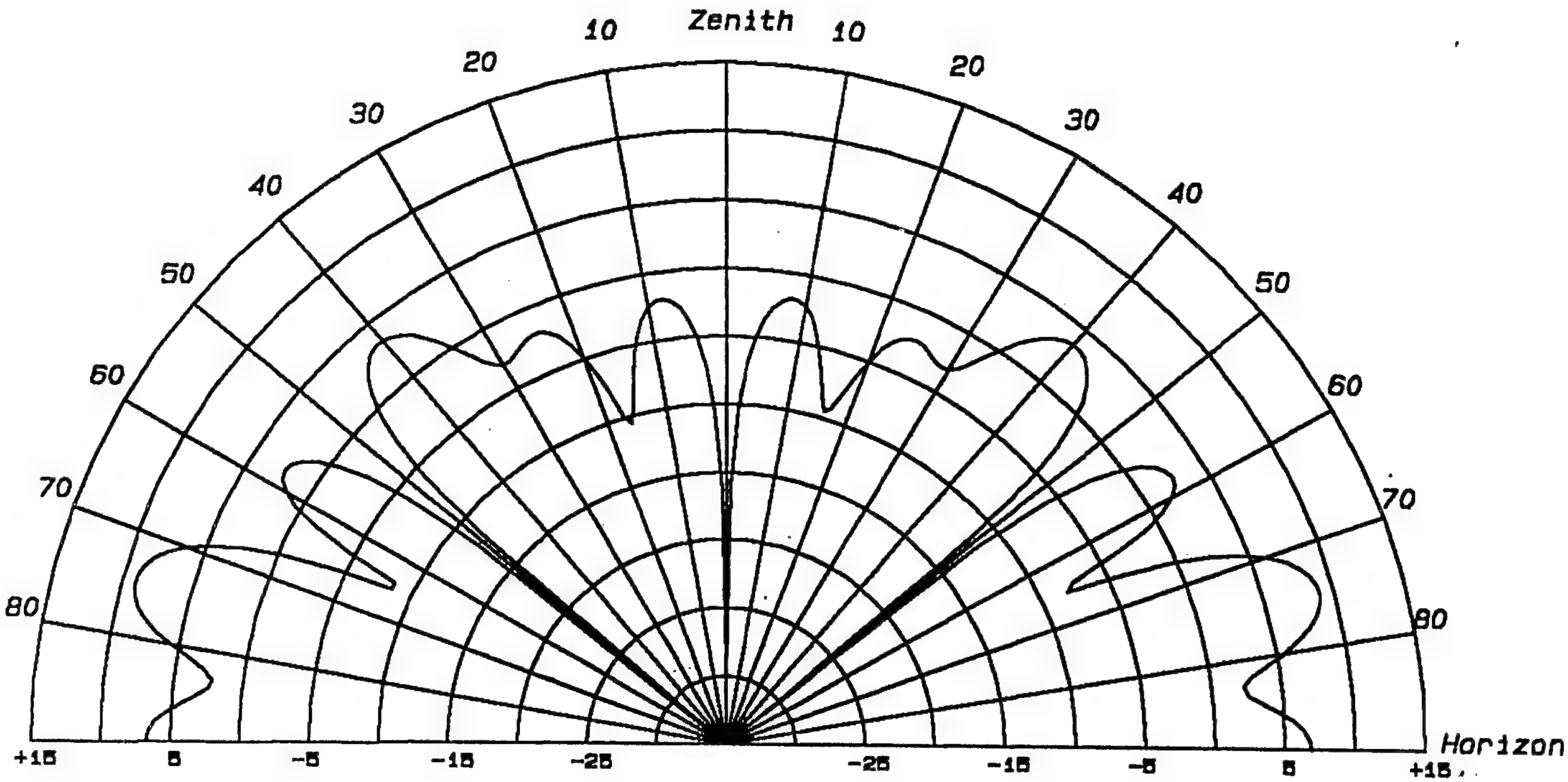
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 55 MHz : Dielectric Mast
Gain = 10.1 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



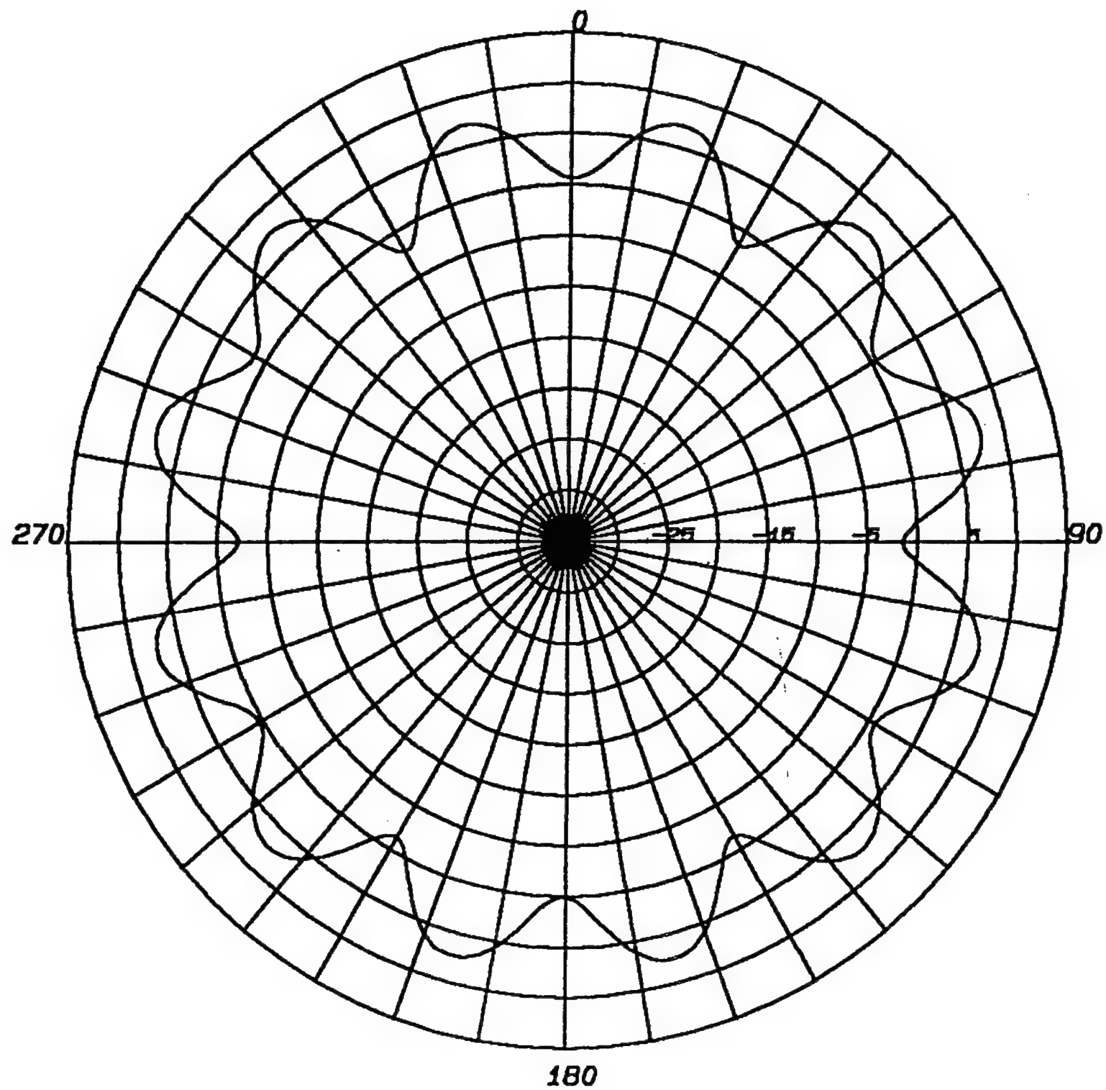
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 60 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



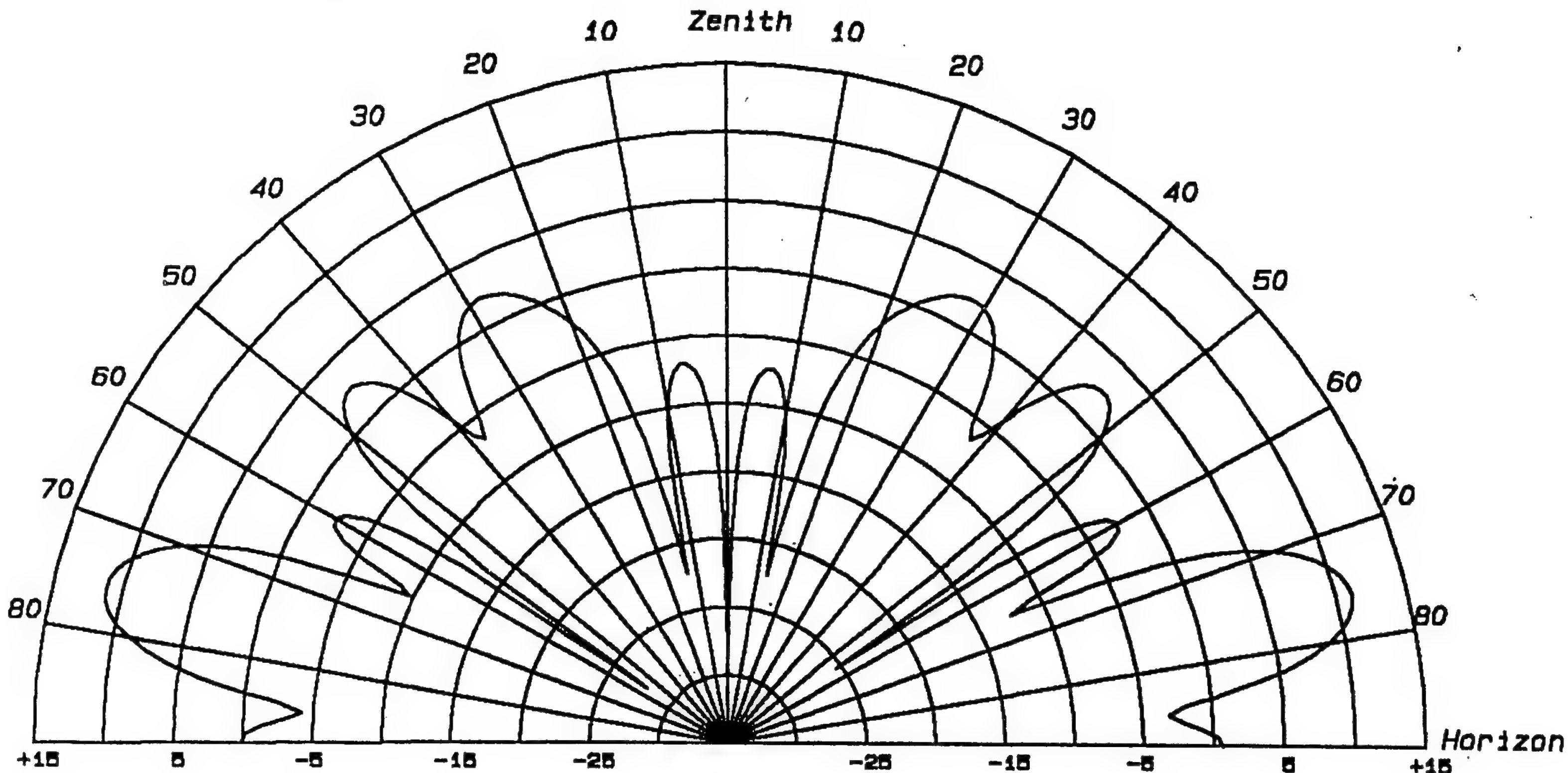
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 60 MHz : Dielectric Mast
Gain = 9.07 dBi : Theta = 75 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



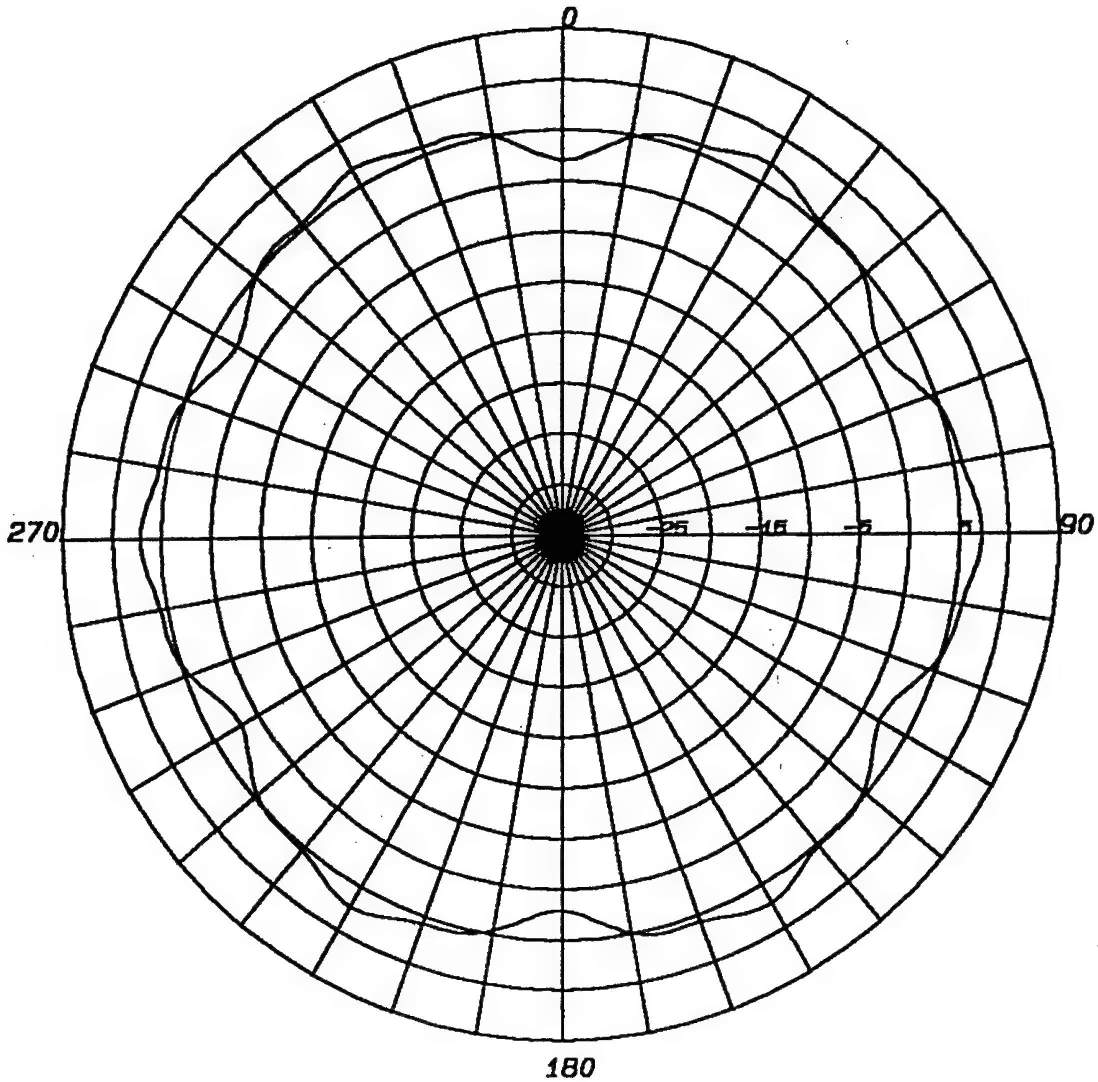
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 65 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



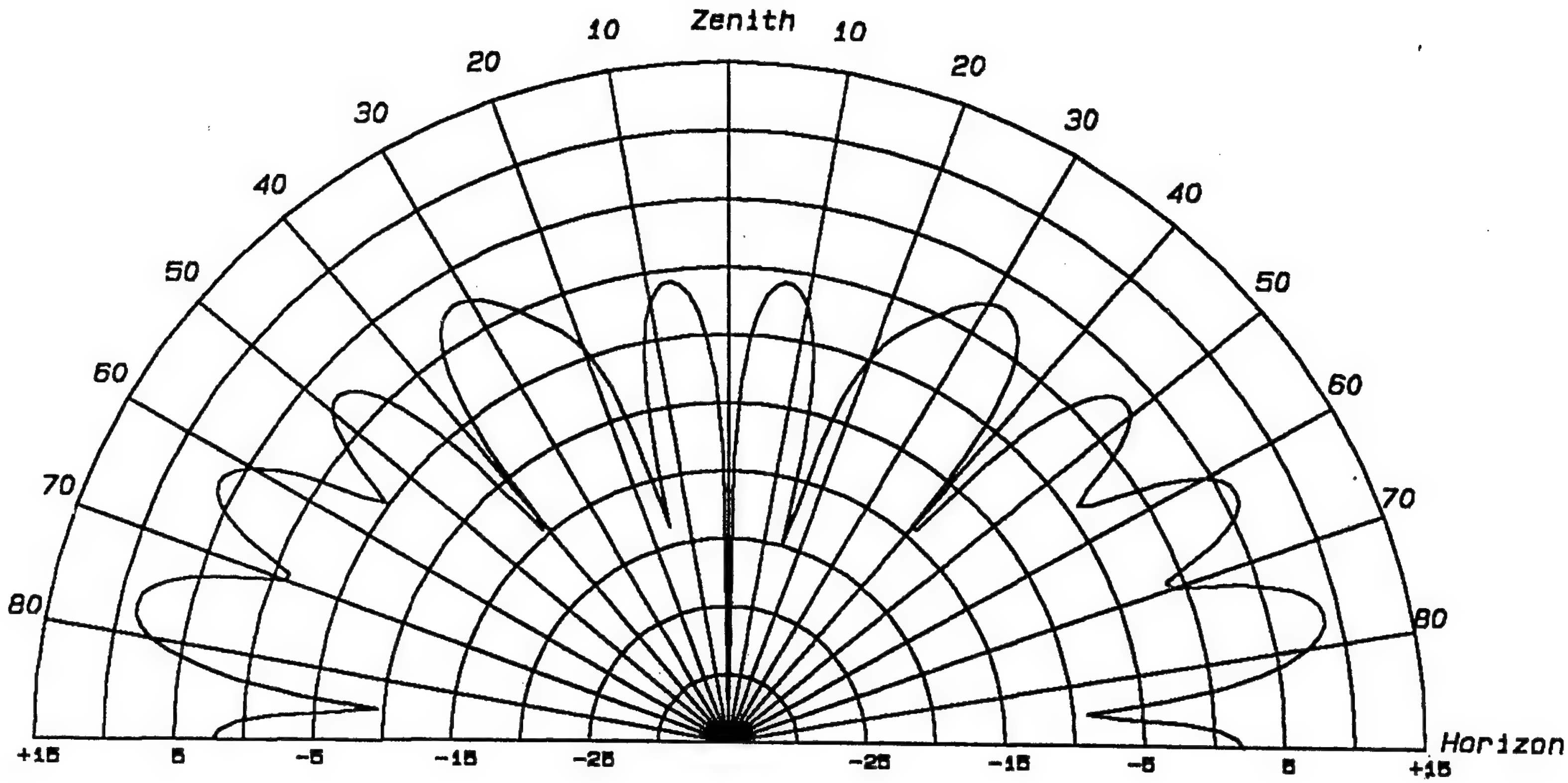
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 65 MHz : Dielectric Mast
Gain = 11.1 dBi : Theta = 76 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



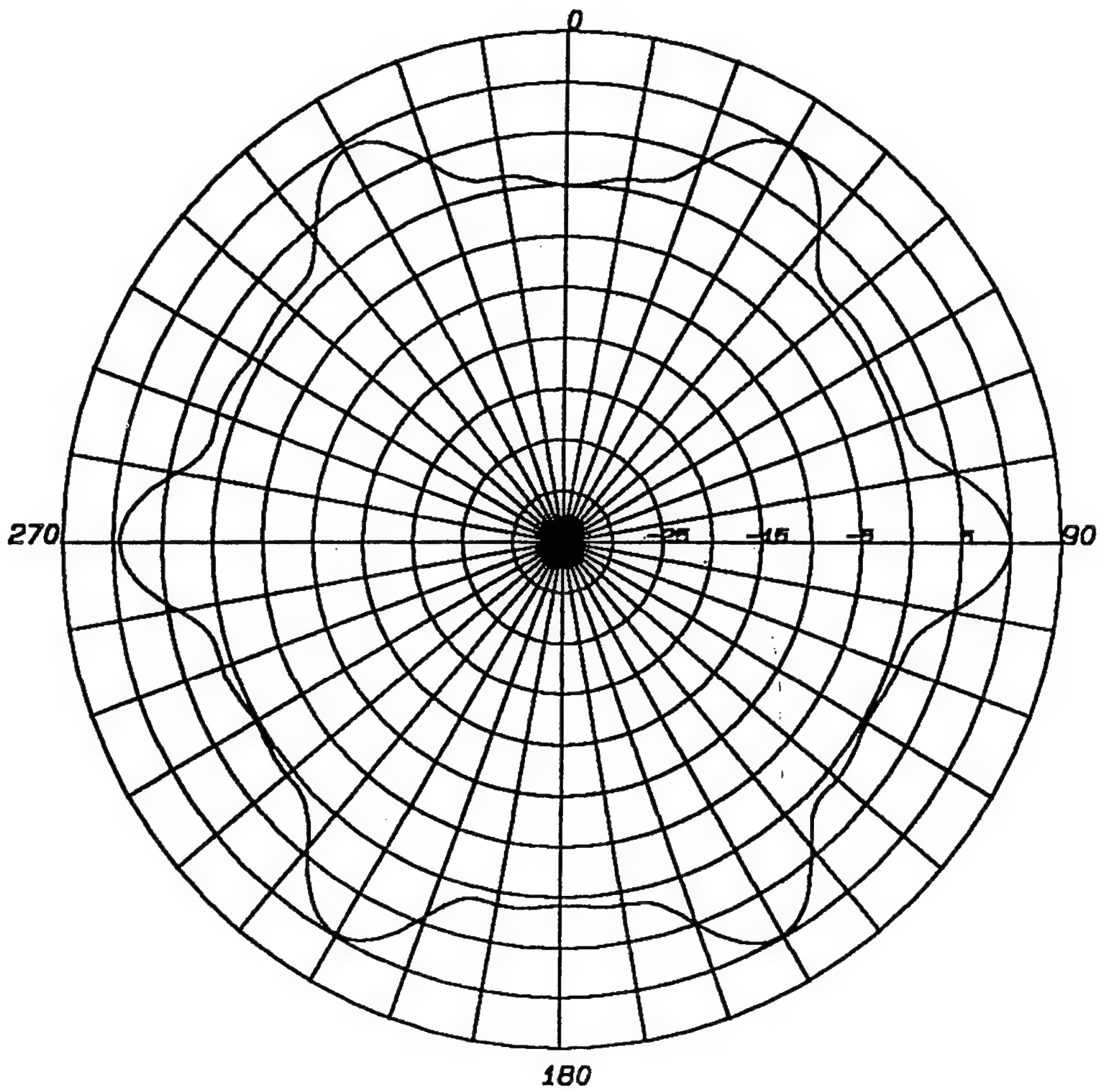
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 70 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



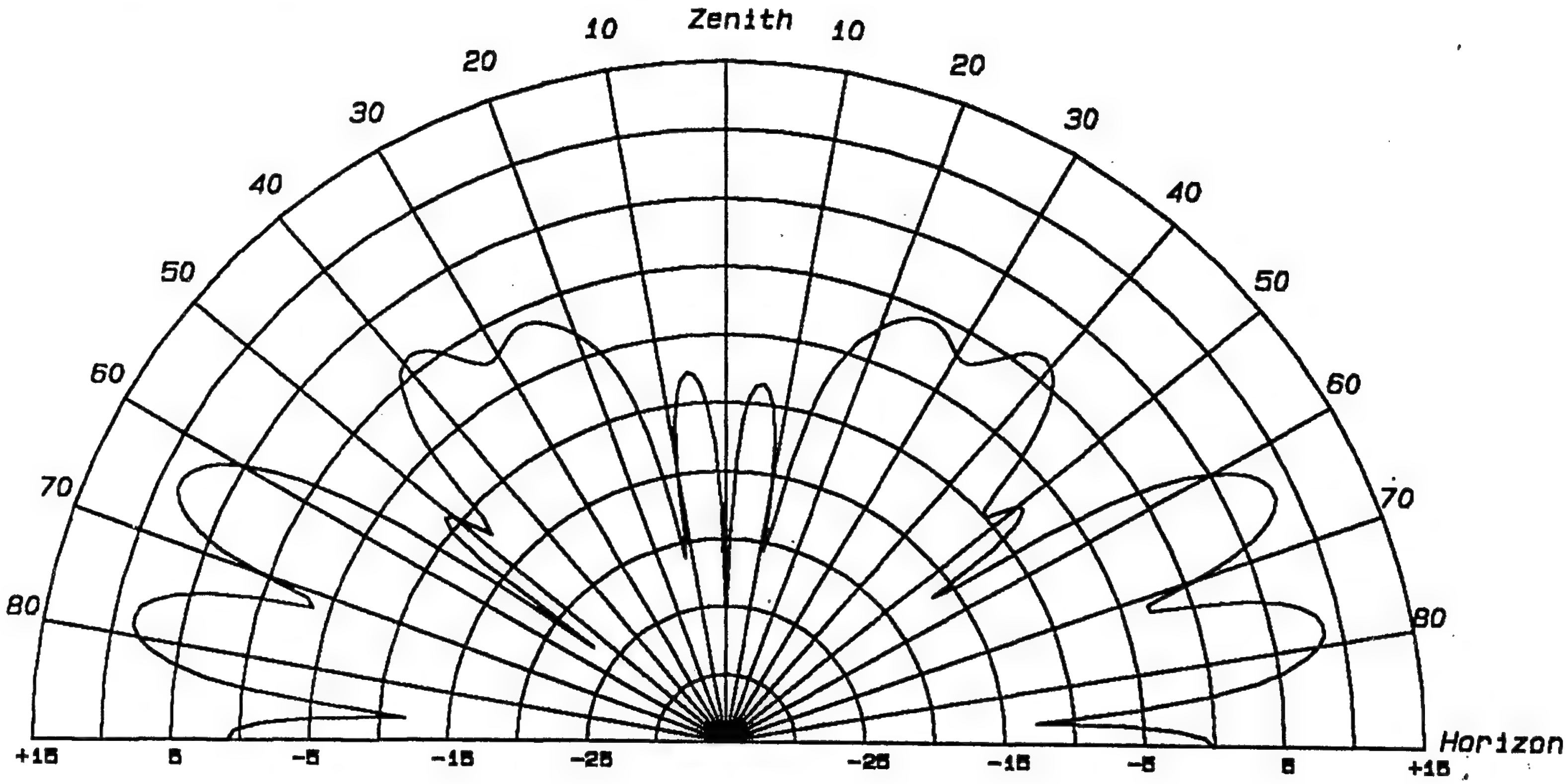
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 70 MHz : Dielectric Mast
Gain = 8.91 dBi : Theta = 77 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



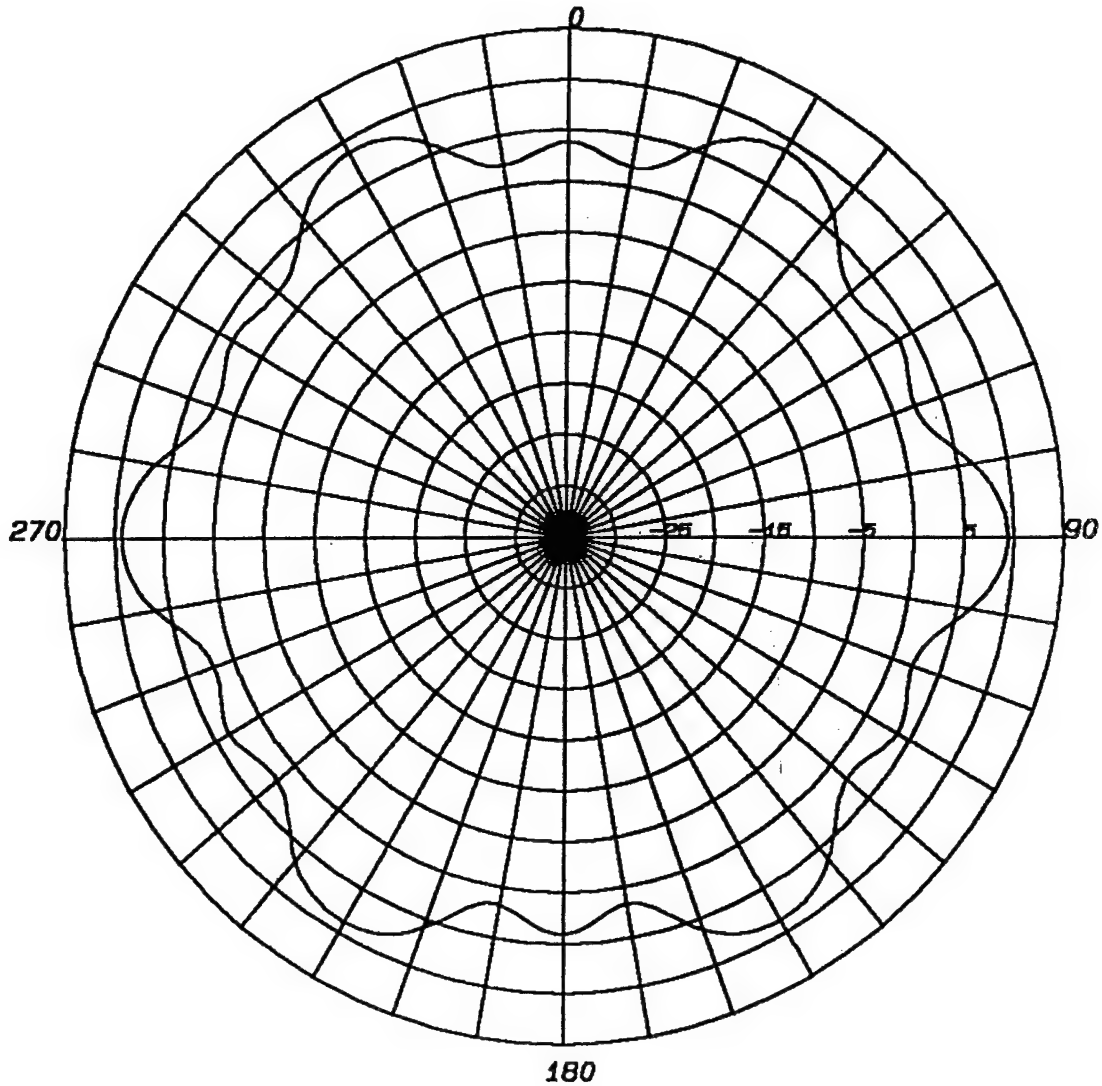
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 75 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



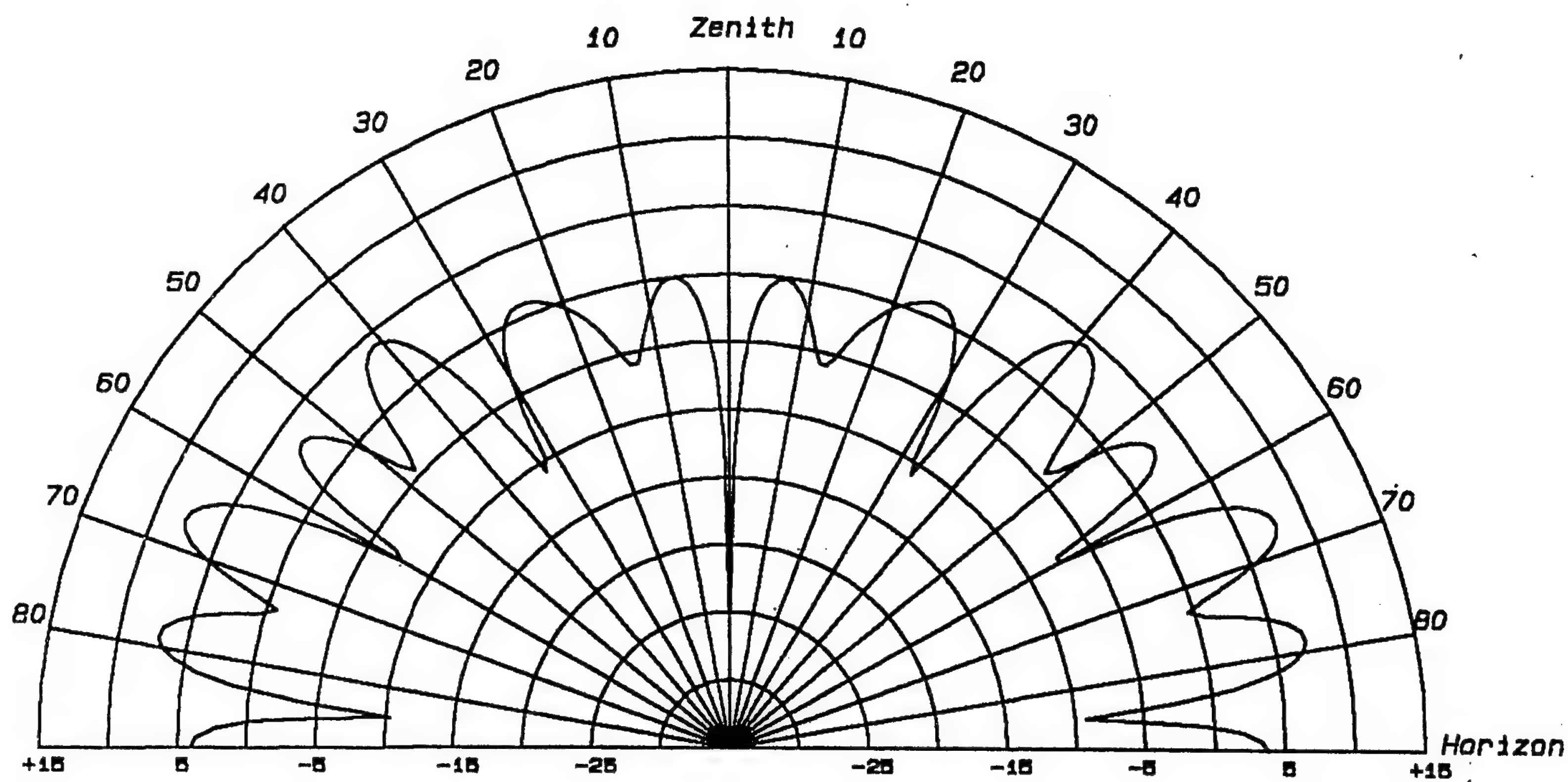
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 75 MHz : Dielectric Mast
Gain = 8.7 dBi : Theta = 78 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 80 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas

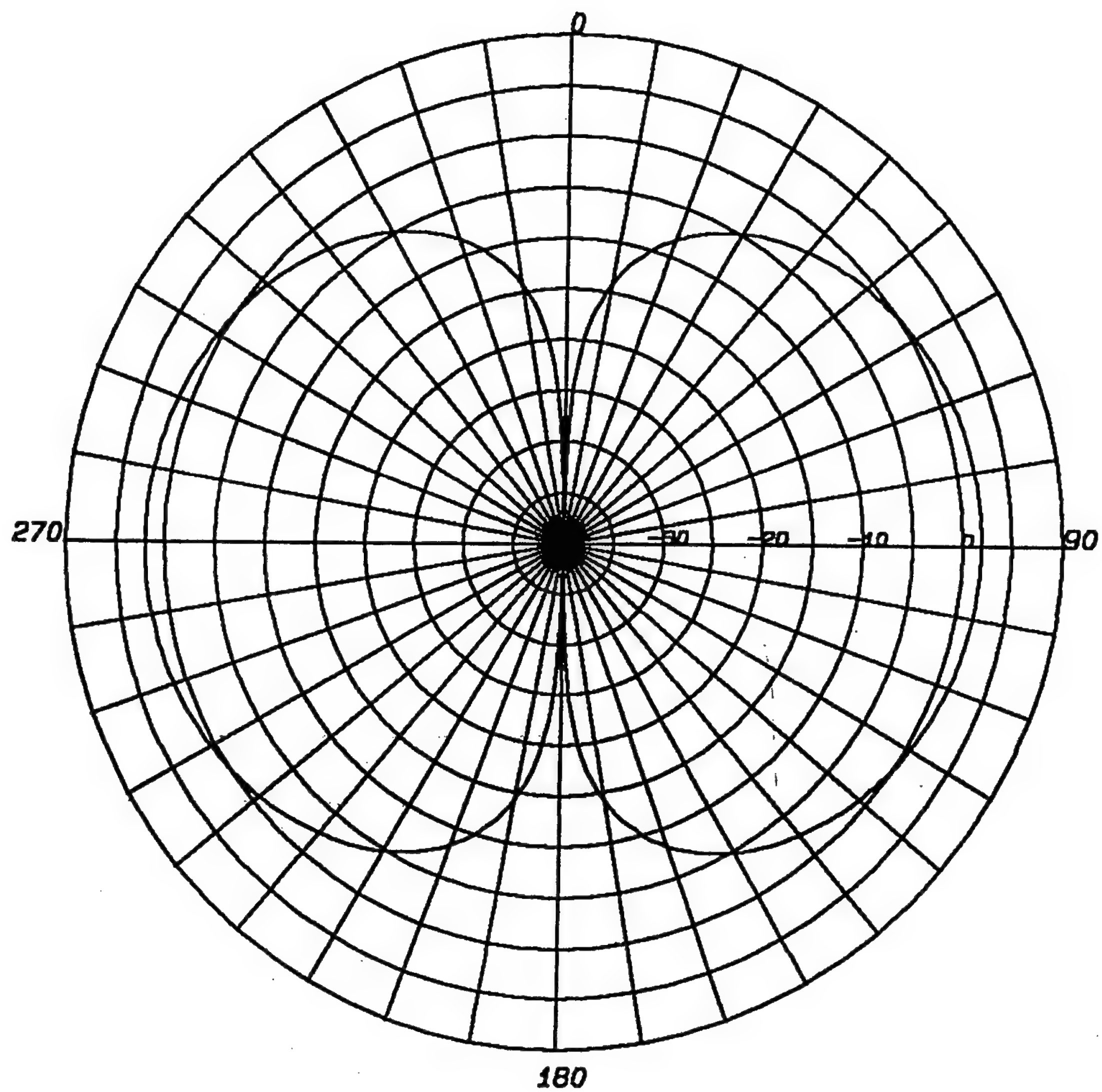


Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 80 MHz : Dielectric Mast
Gain = 7.78 dBi : Theta = 67 Degrees
Perfect Ground : Leg = 10 Meters

APPENDIX D

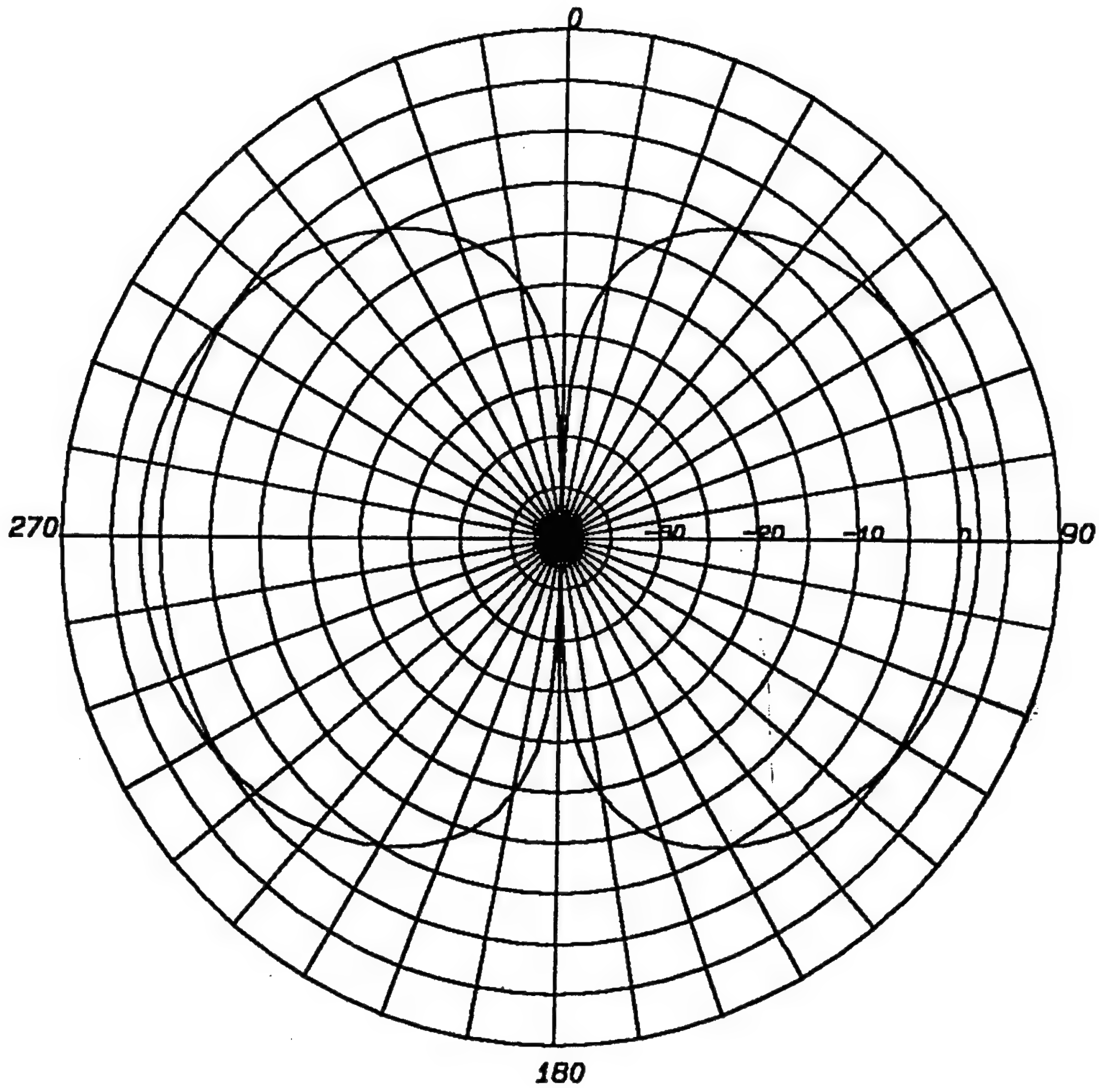
Radiation Patterns of the VHF Antenna of Configuration C

Antenna Products Corp.
Mineral Wells, Texas



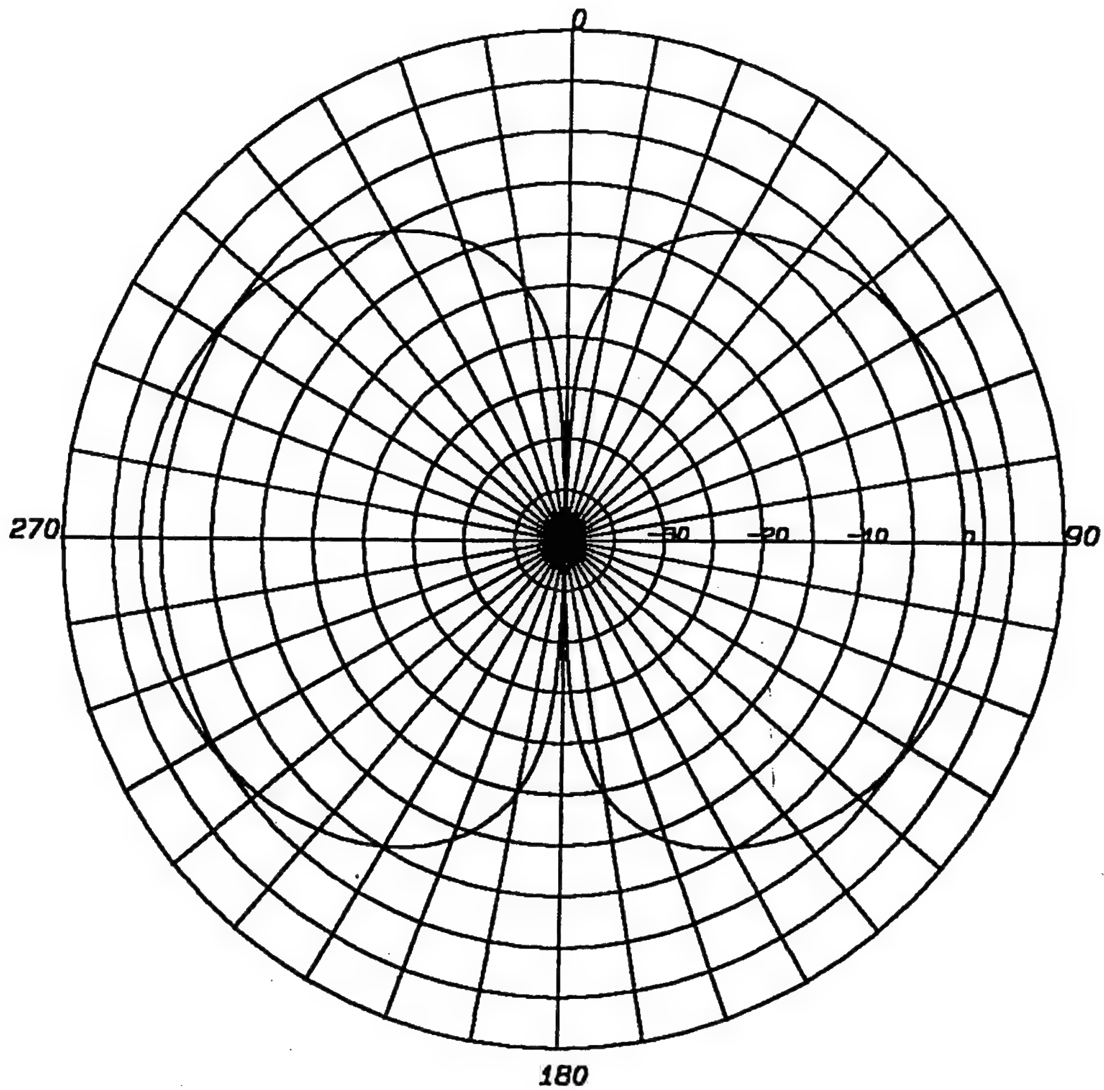
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 30 MHz : Scale is dBi
Gain = 1.95 dBi : Theta = 88 Degrees

Antenna Products Corp.
Mineral Wells, Texas



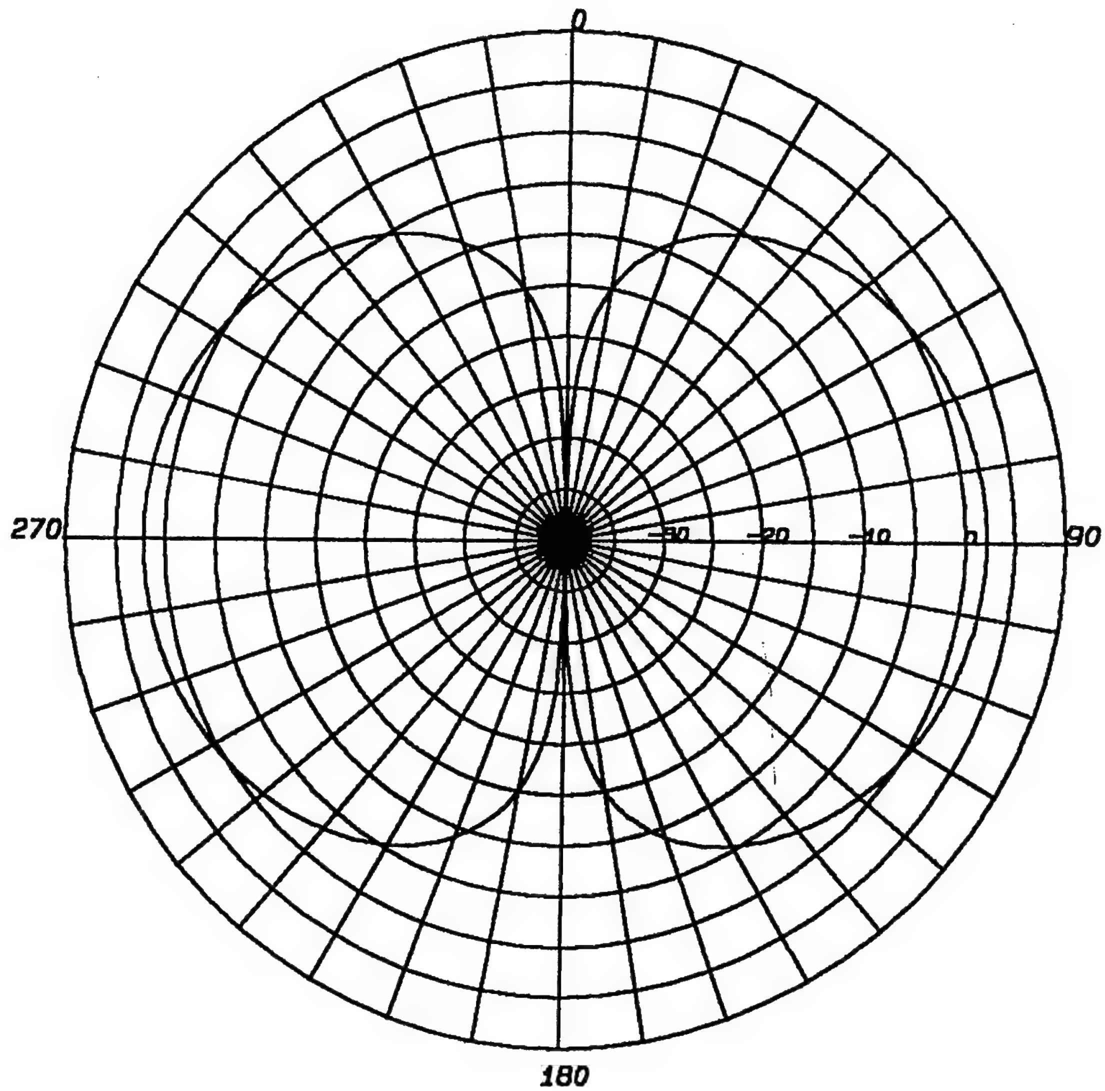
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 34 MHz : Scale is dBi
Gain = 2.01 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



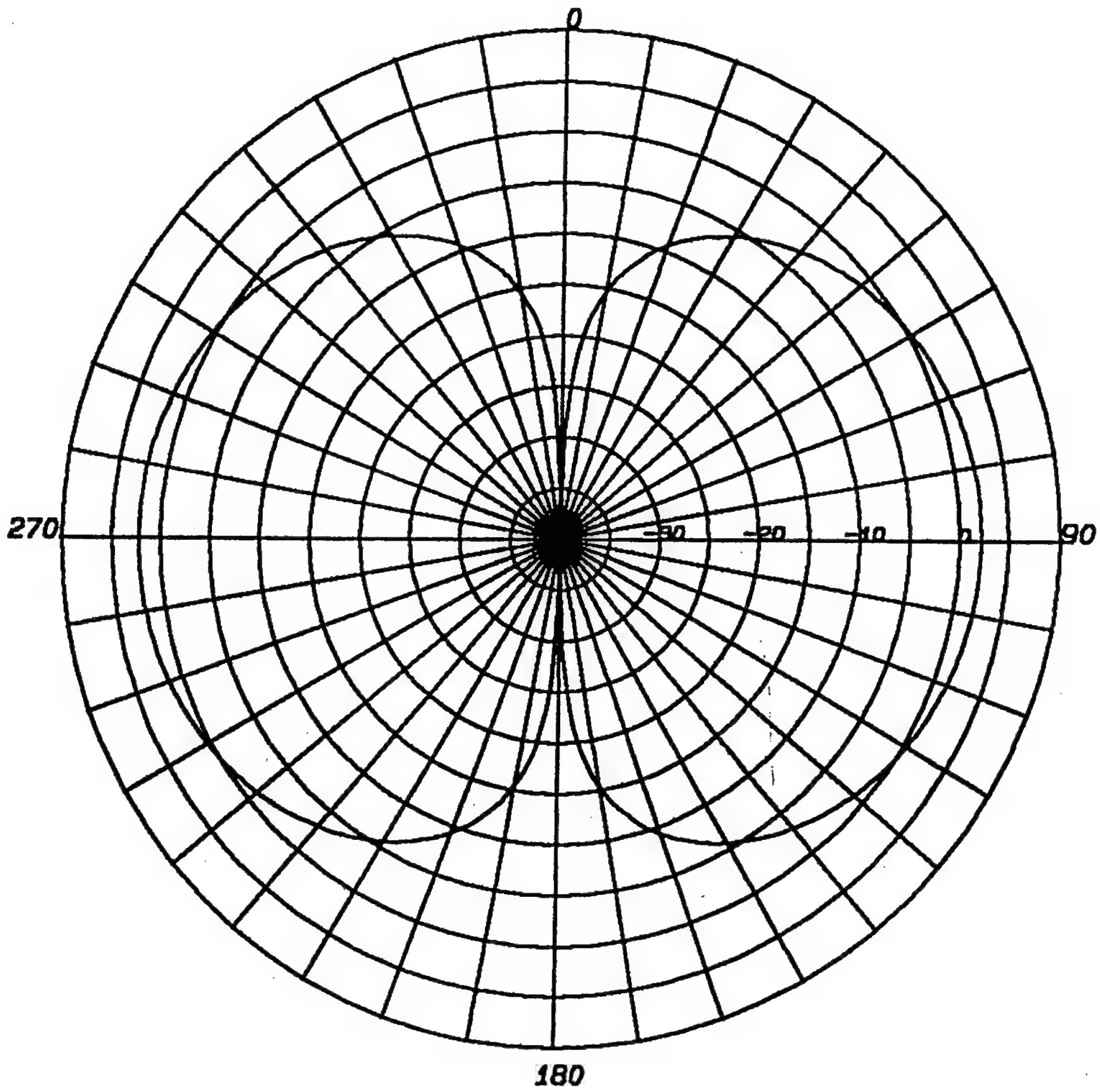
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 38 MHz : Scale is dBi
Gain = 2.07 dBi : Theta = 88 Degrees

Antenna Products Corp.
Mineral Wells, Texas



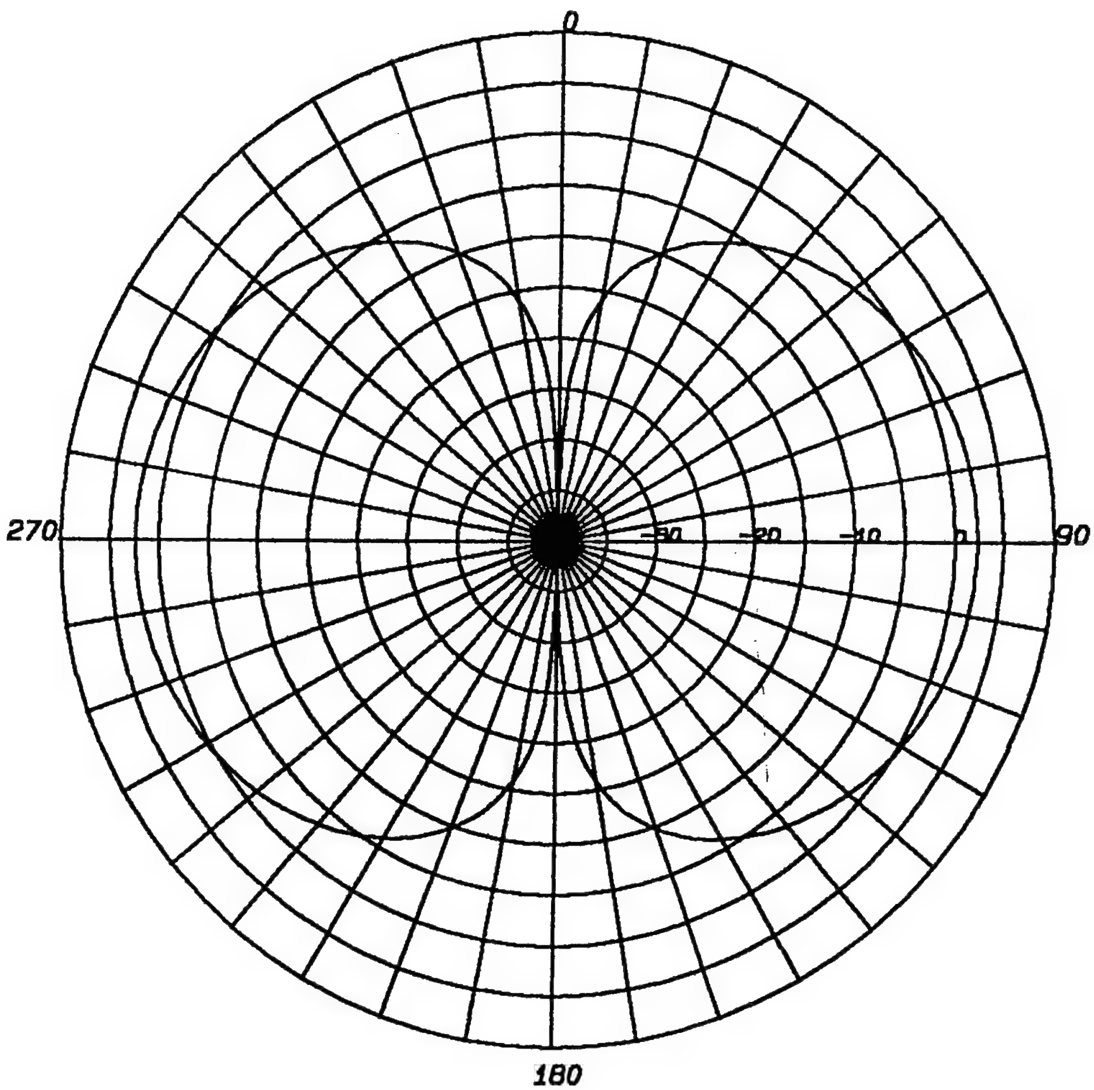
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 42 MHz : Scale is dBi
Gain = 2.15 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



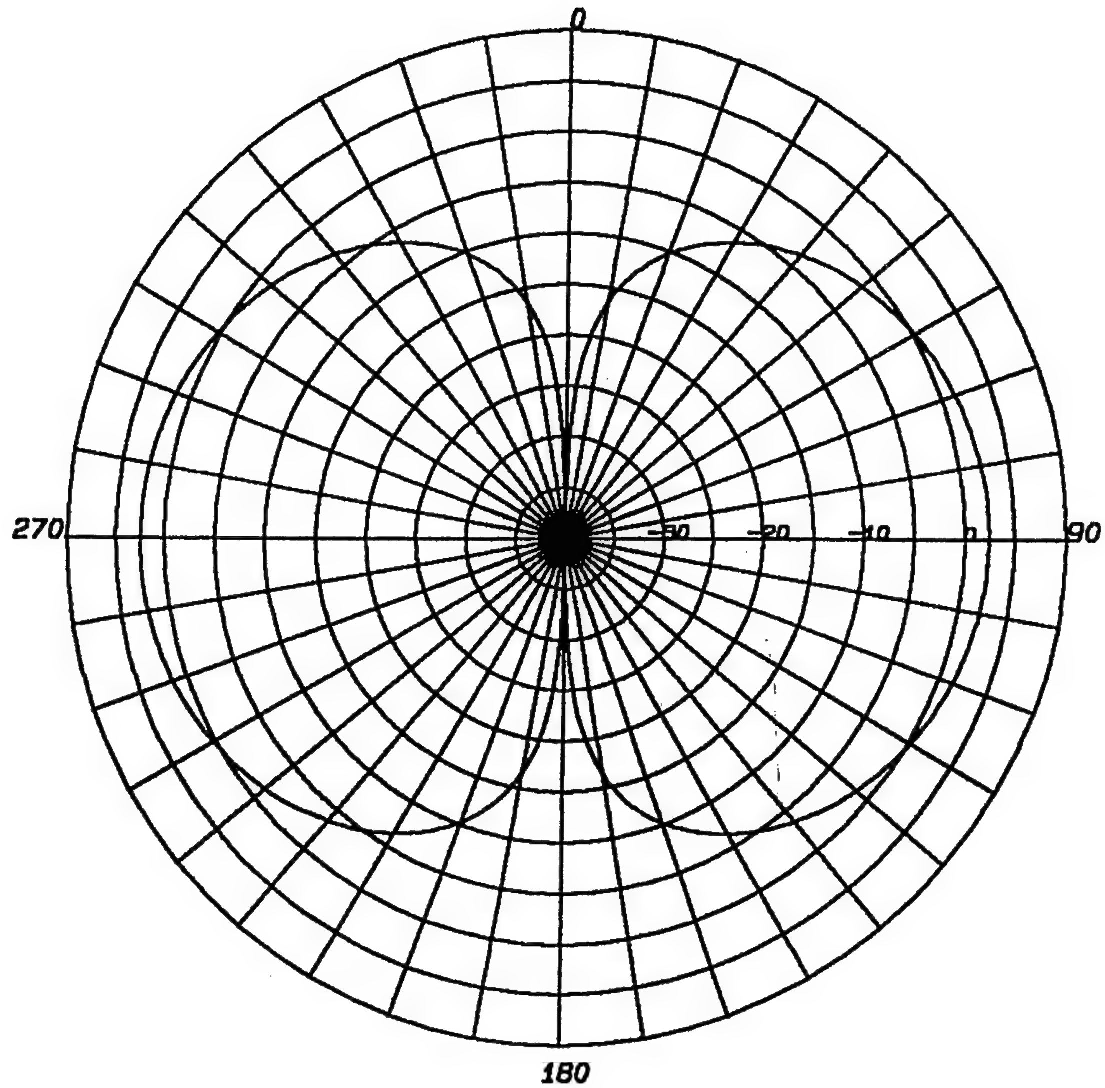
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 46 MHz : Scale is dBi
Gain = 2.23 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



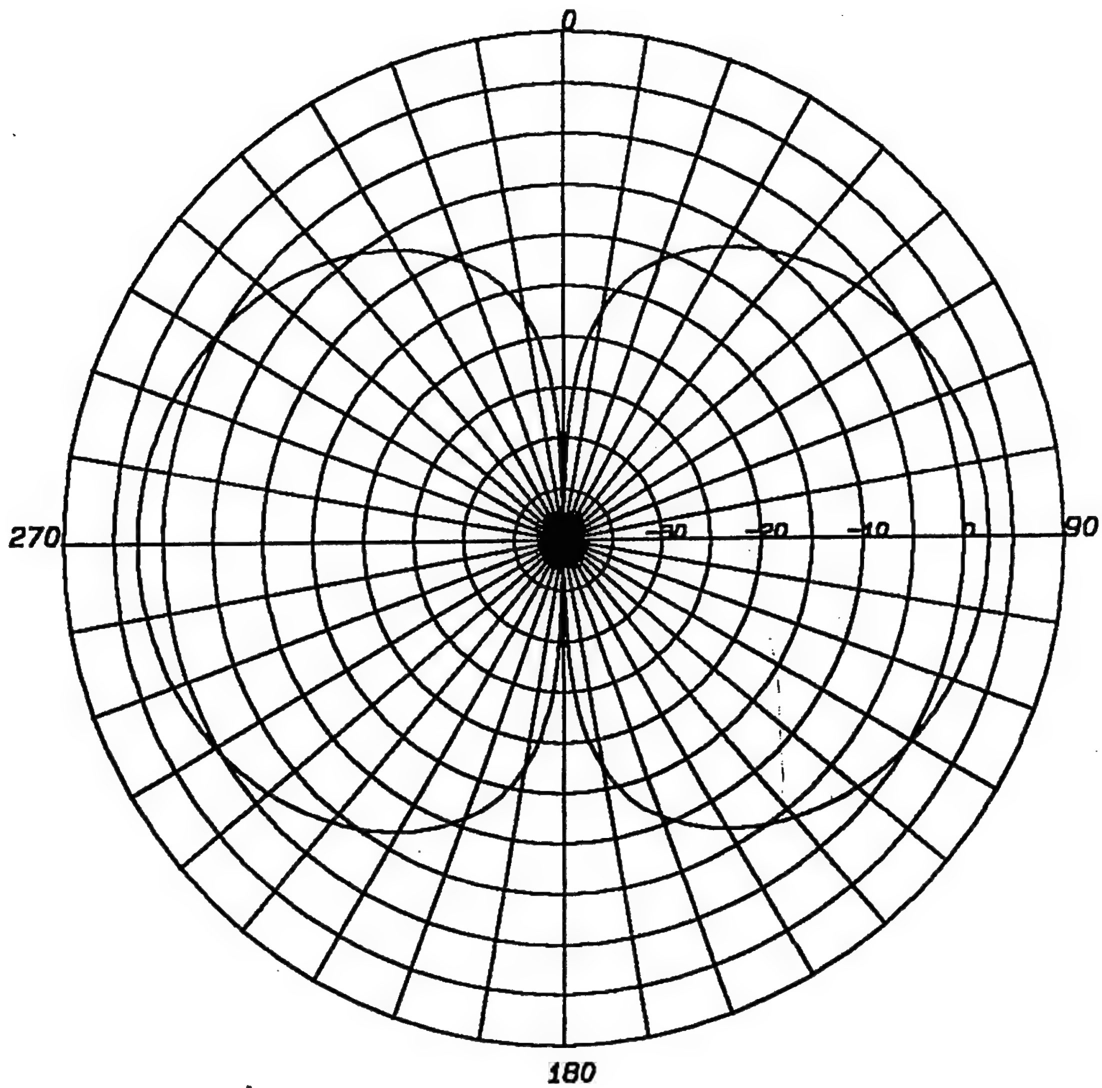
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 50 MHz : Scale is dBi
Gain = 2.33 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



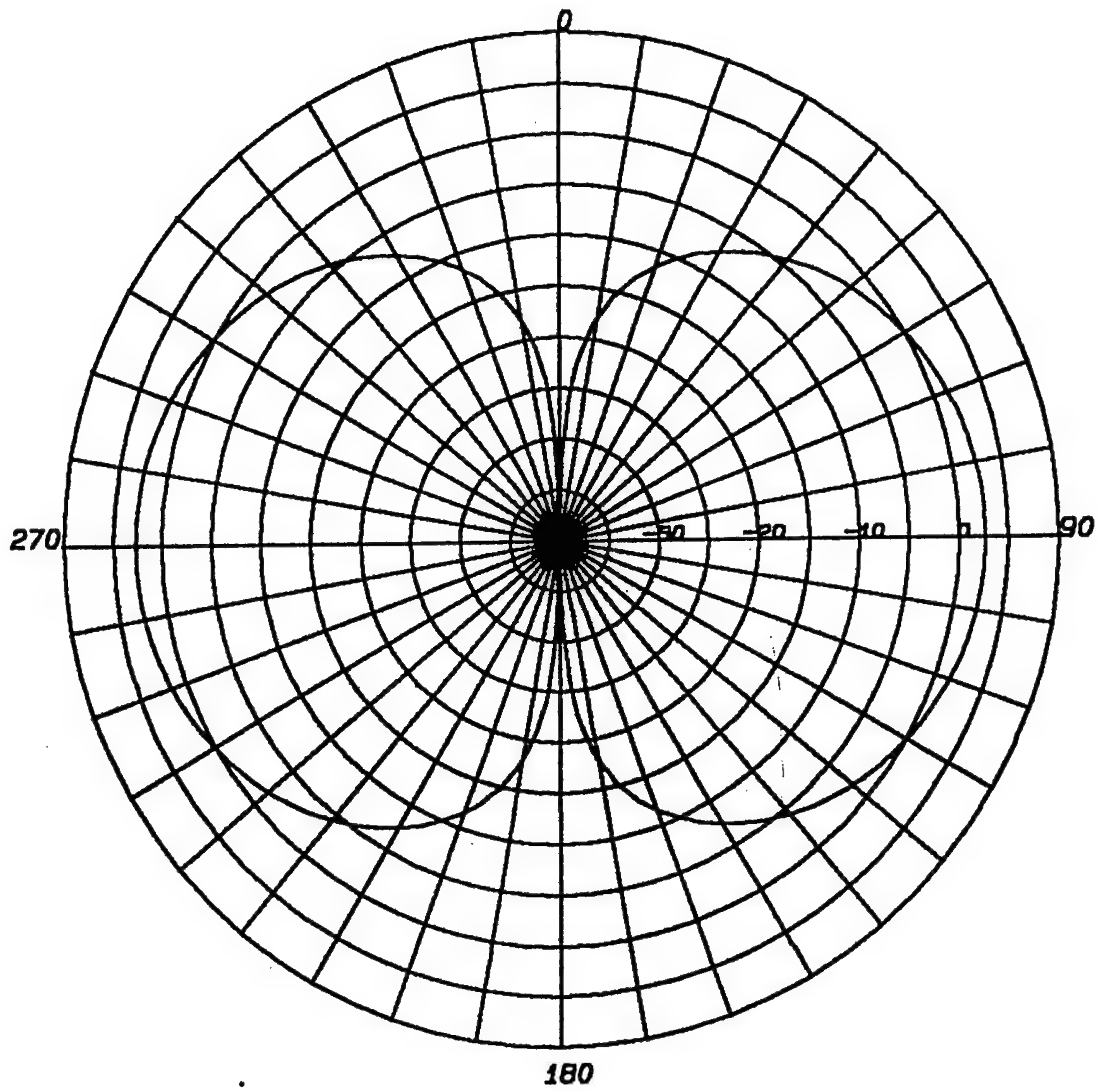
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 54 MHz : Scale is dBi
Gain = 2.44 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



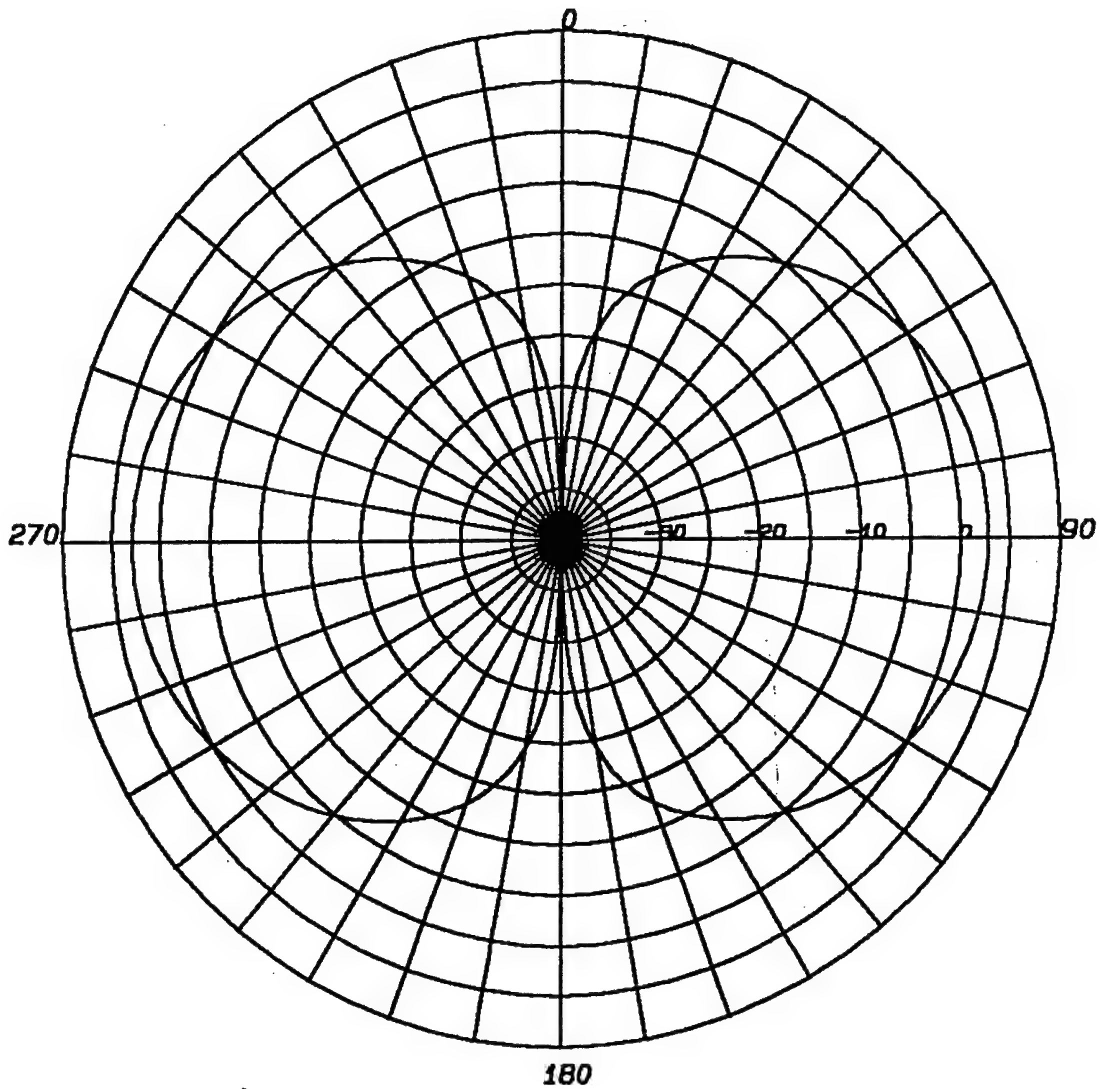
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 58 MHz : Scale is dBi
Gain = 2.56 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



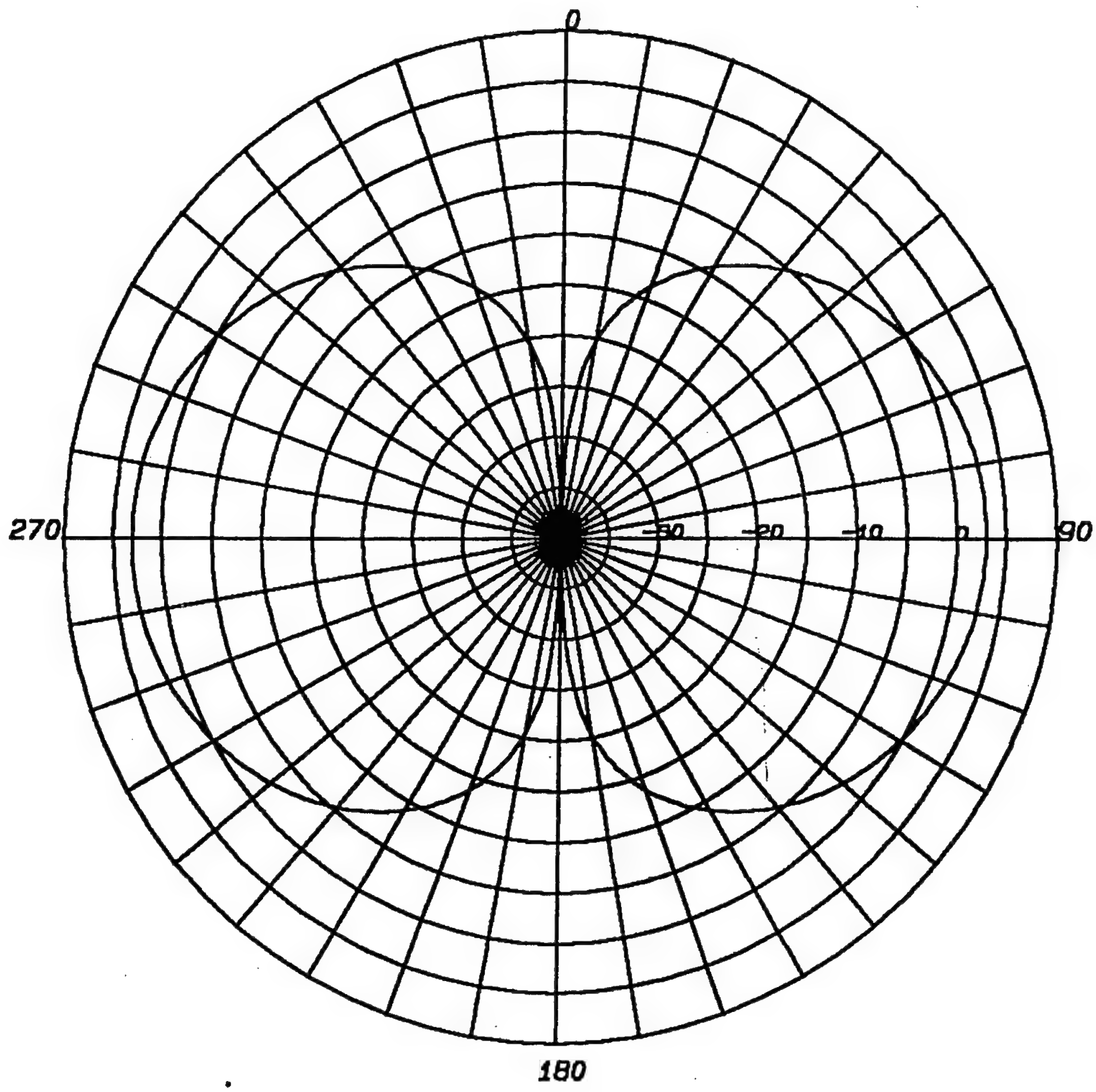
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 62 MHz : Scale is dBi
Gain = 2.69 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



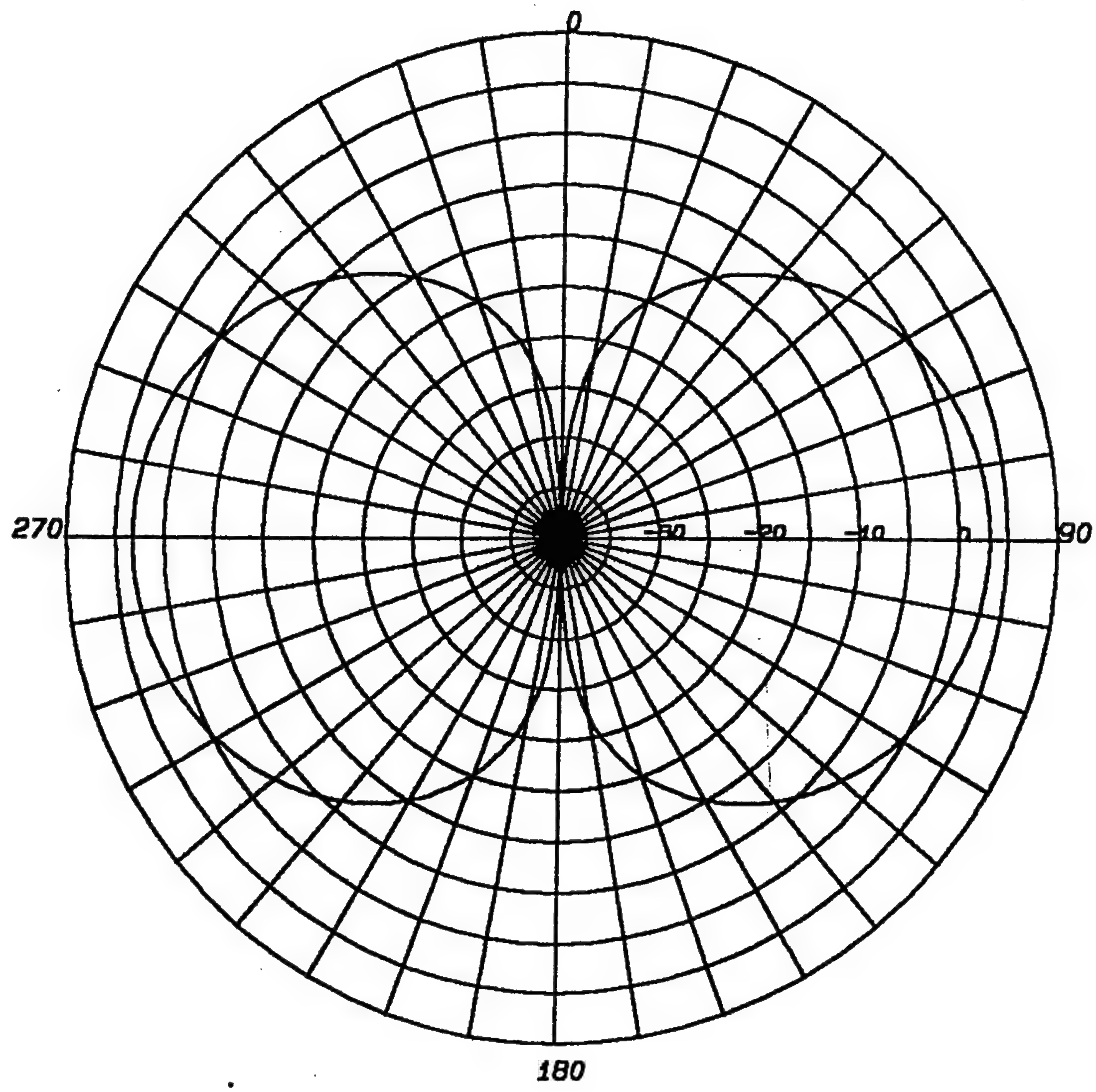
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 66 MHz : Scale is dBi
Gain = 2.84 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



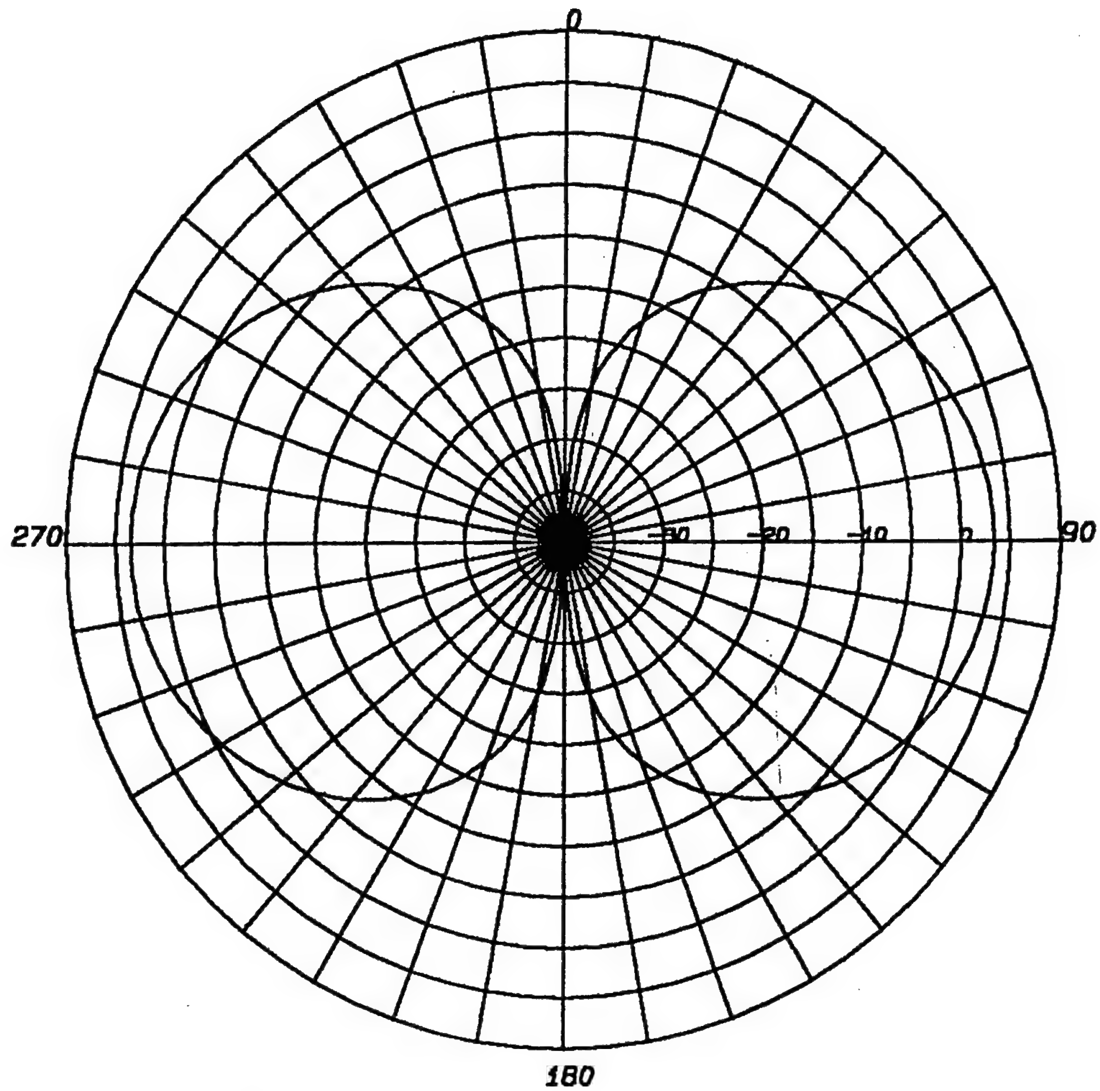
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 70 MHz : Scale is dBi
Gain = 3 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



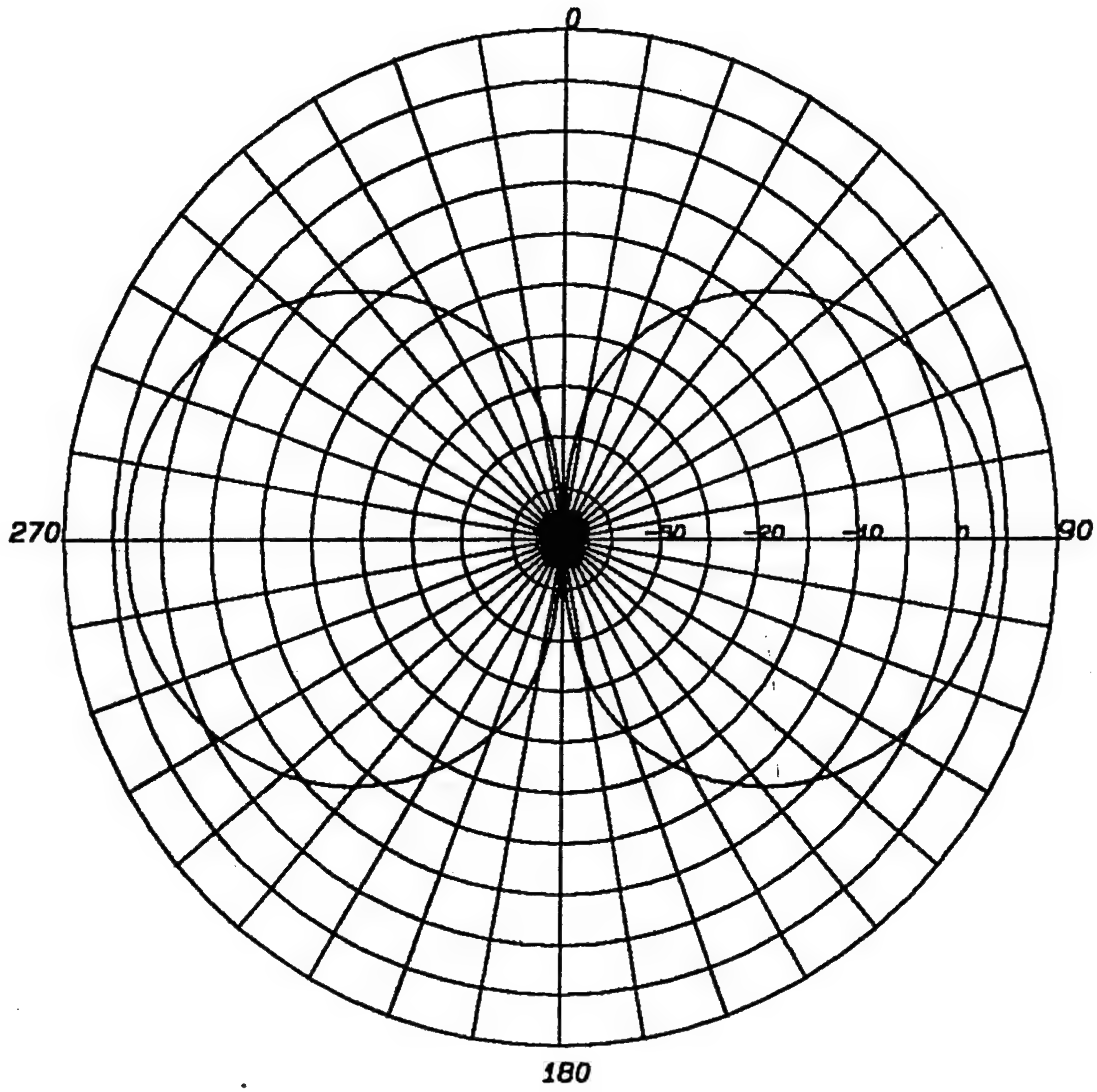
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 74 MHz : Scale is dBi
Gain = 3.18 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



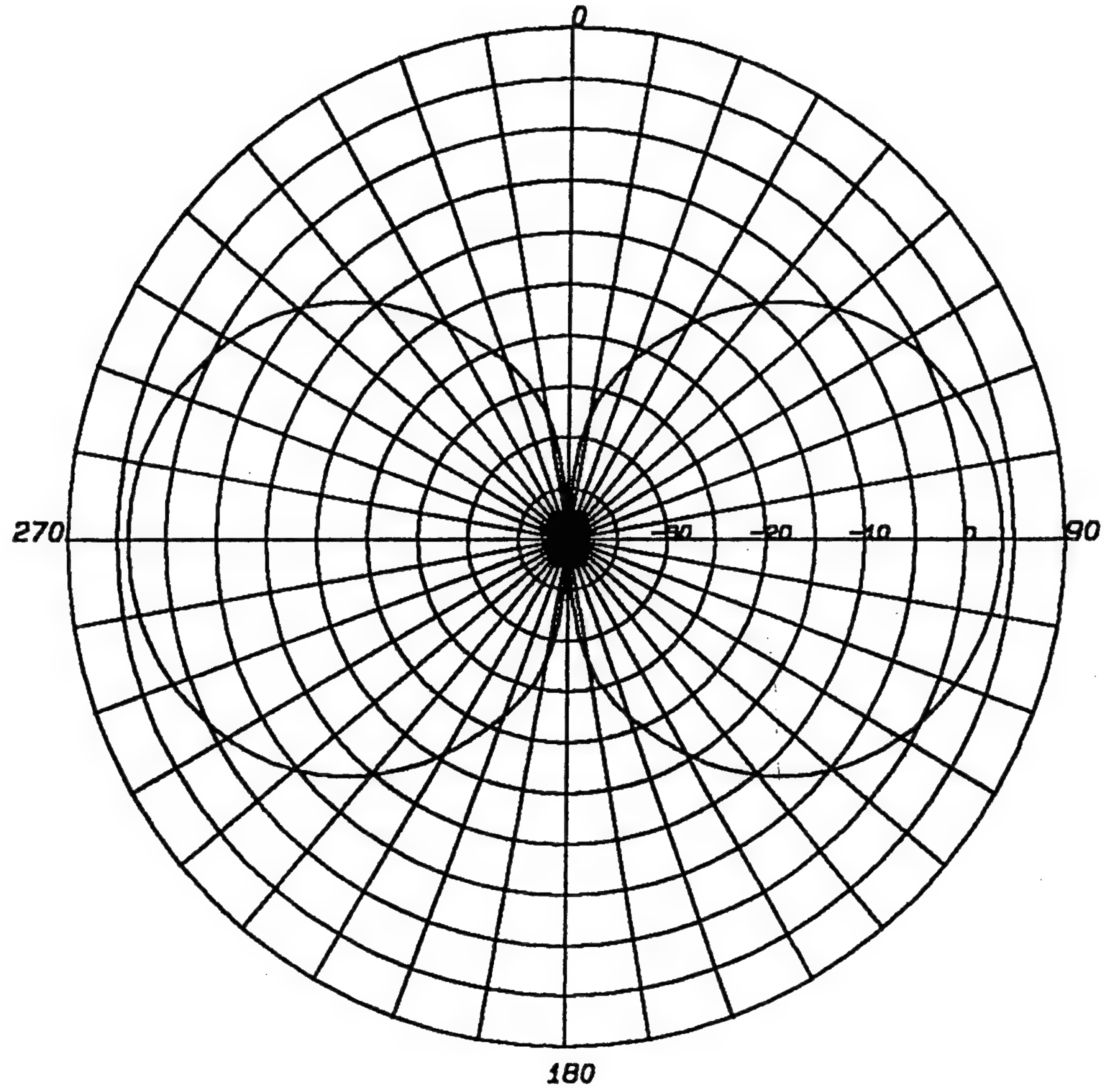
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 78 MHz : Scale is dBi
Gain = 3.37 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



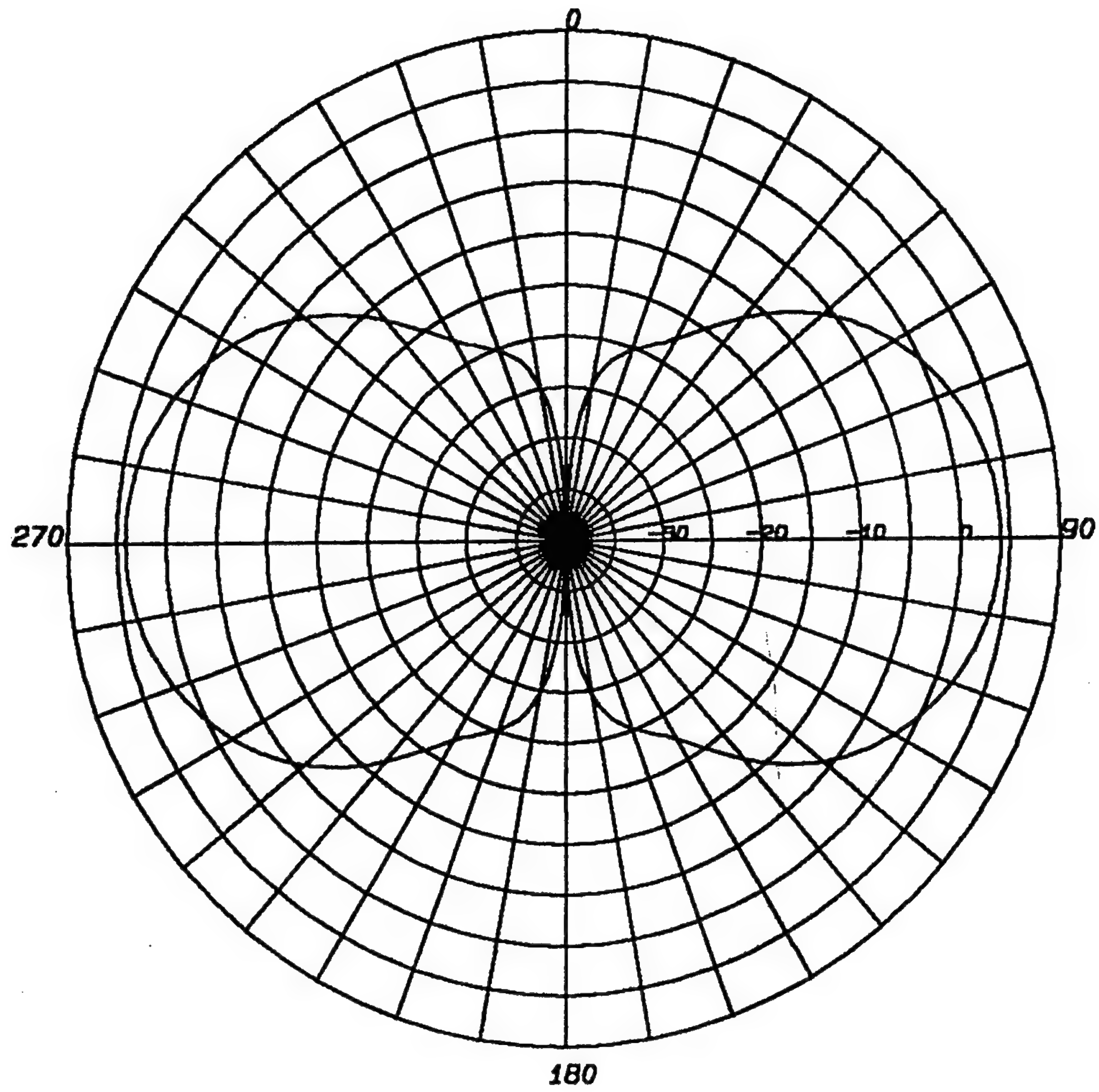
1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 82 MHz : Scale is dBi
Gain = 3.59 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 86 MHz : Scale is dBi
Gain = 3.82 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



1.68 m Dipole Antenna (4 uhf, .4m)
Frequency = 90 MHz : Scale is dBi
Gain = 4.06 dBi : Theta = 90 Degrees

APPENDIX E

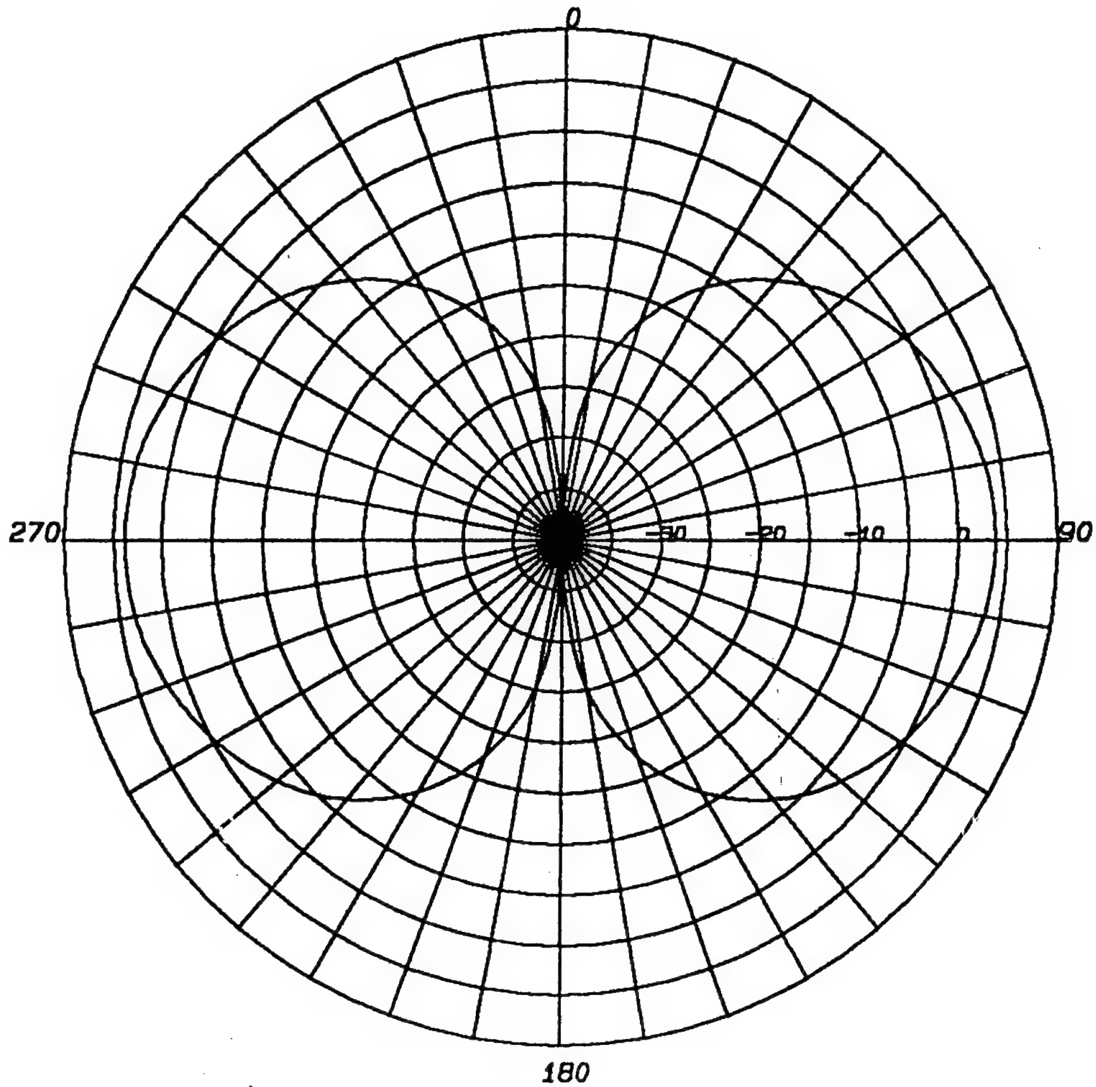
UHFA.BAS
U.BAS
OPTA.BAS
OPT.BAS

```
CLS
COLOR 2
PI = 4 * ATN(1)
DIM X(50), Y(50), Z(50), A(50)
REM THIS PROGRAM IS TO GENERATE INPUT DATA FOR NEC3 TO COMPUTE
REM IMPEDANCE FILE FOUR UHF DIPOLE ANTENNAS CONFIGURATION.
FL = 225
FH = 450
L2 = 1.68                              'HALF LENGTH OF VHF DIPOLE
D = .05                                'OFF-SET OF UHF DIPOLES
OP$ = "PARO.TXT"                       'PARAMETER OUTPUT FILE
L = .4                                 'LENGTH OF UHF DIPOLES
R = .0125                              'RADIUS OF DIPOLES
O$ = "UHFO.IN"                         'INITIAL INPUT FILE FOR NEC-3
OPEN OP$ FOR OUTPUT AS 2
PRINT #2, L, R
CLOSE 2
N = 40                                'NUMBER OF FREQUENCIES
TAU = EXP(LOG(FL / FH) / (N - 1))
K = 1 / TAU                           'FREQUENCY SCALE FACTOR

OPEN O$ FOR OUTPUT AS 1
PRINT #1, "CM THIS DATA WAS GENERATED USING UHFA.BAS 06 MAR 98"
PRINT #1, "CM DATA IS FOR ANALYSIS USING DNEC1200"
PRINT #1, "CE"
A$ = "GW"
B$ = ","
W = 1
S = 51
S1 = 11
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S; B$;
PRINT #1, 0; B$; 0; B$; -L2; B$; 0; B$; 0; B$; L2; B$; R
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; D; B$; D; B$; 0; B$; D; B$; D + L; B$; R
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; D; B$; -D - L; B$; 0; B$; D; B$; -D; B$; R
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; -D; B$; D; B$; 0; B$; -D; B$; D + L; B$; R
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; -D; B$; -D - L; B$; 0; B$; -D; B$; -D; B$; R

REM END OF GEOMETRY CARD
A$ = "GE"
I1 = 0: I2 = 0
PRINT #1, TAB(1); A$;
PRINT #1, I1; B$; I2

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 2: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = 50
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
```

```
I1 = 0: I2 = 3: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = 50
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 4: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = 50
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 5: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = 50
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM FREQUENCY CARD
A$ = "FR"
PRINT #1, TAB(1); A$;
I1 = 1: I2 = 40
F1 = 225: F2 = K
PRINT #1, I1; B$; I2; B$; 0; B$; 0; B$; F1; B$; F2

REM PLOT CARD
A$ = "PL"
PRINT #1, TAB(1); A$;
I1 = 4
PRINT #1, I1

REM EXECUTE CARD
A$ = "XQ"
PRINT #1, TAB(1); A$;
I1 = 0
PRINT #1, I1

REM END CARD
A$ = "EN"
PRINT #1, TAB(1); A$
CLOSE 1
END
```

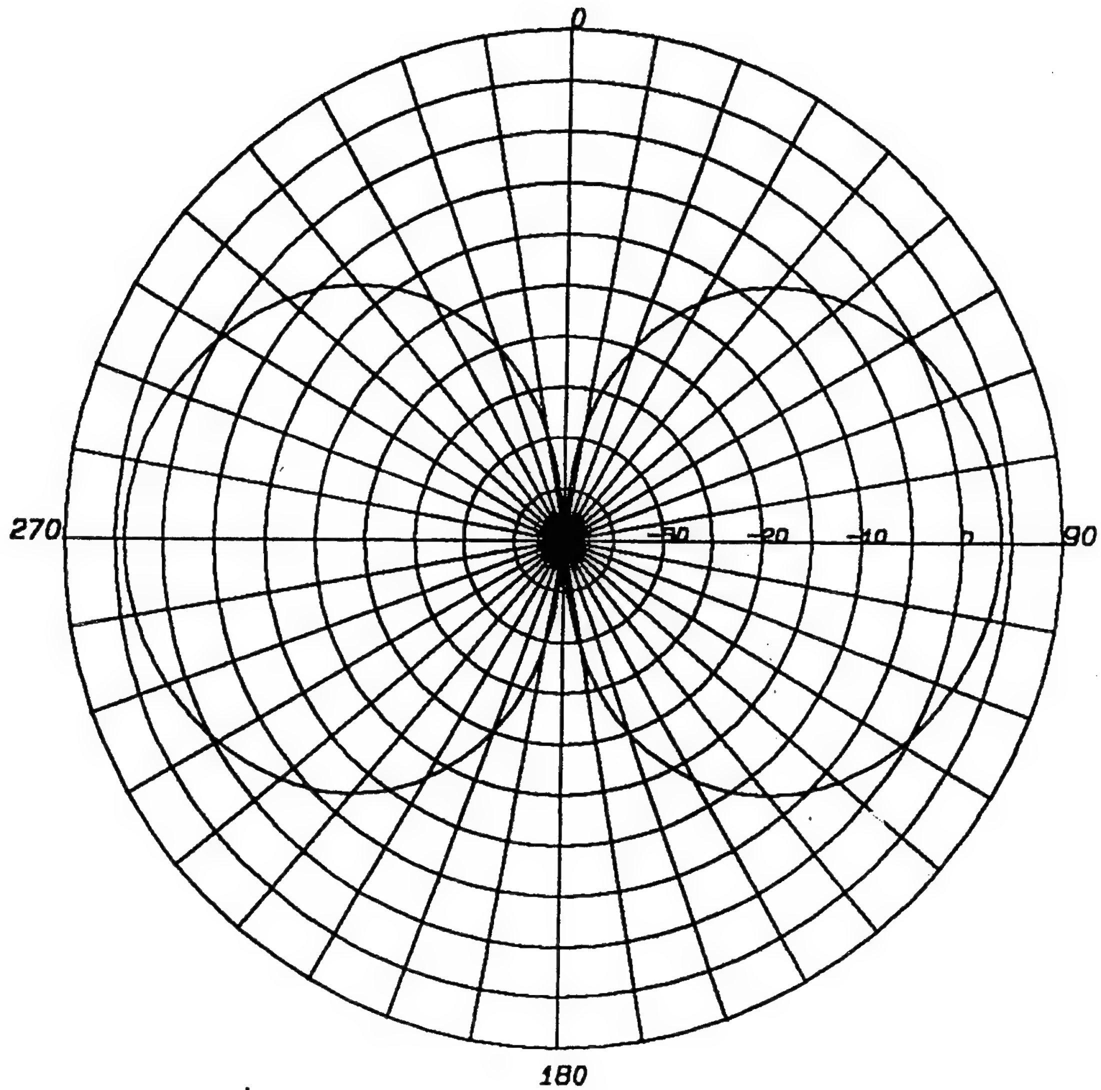
```
CLS
COLOR 2
PI = 4 * ATN(1)
DIM X(50), Y(50), Z(50), A(50), T(10), L(10), R(10)
REM UHF.BAS : 18 MARCH 1998 : ROSS L. BELL
REM THIS PROGRAM IS TO GENERATE INPUT DATA FOR NEC3
REM UHF & VHF DIPOLE COMBINATION ANTENNA.
FL = 225
FH = 450
Z0 = 50
REM L = .44                                'LENGTH OF UHF DIPOLE
REM R = .0125                              'RADIUS OF UHF DIPOLE
R2 = .0125                                 'RADIUS OF VHF DIPOLE
H2 = 1.68                                  'LENGTH OF VHF DIPOLE
REM T = .08                                'OFF-SET OF UHF DIPOLE Y-DIR
D = .05                                    'OFF-SET OF UHF DIPOLES Z-DIR
K = .99                                    'SCALING FACTOR
NF = 40                                    'NUMBER OF FREQUENCIES
TAU = EXP(LOG(FL / FH) / (NF - 1))
K1 = 1 / TAU                               'FREQUENCY SCALE

I$ = "PARA.TXT"
OPEN I$ FOR INPUT AS 1
INPUT #1, TT, LL, RR, N, SM, FM, L1, C1, L2, C2
T = INT(TT * 10000 + .5) / 10000
L = INT(LL * 10000 + .5) / 10000
R = INT(RR * 100000 + .5) / 100000
CLOSE 1
T(1) = INT(T * K * 10000 + .5) / 10000: L(1) = L: R(1) = R
T(2) = INT(T / K * 10000 + .5) / 10000: L(2) = L: R(2) = R
T(3) = T: L(3) = INT(L * K * 10000 + .5) / 10000: R(3) = R
T(4) = T: L(4) = INT(L / K * 10000 + .5) / 10000: R(4) = R
T(5) = T: L(5) = L: R(5) = INT(R * K * 100000 + .5) / 100000
T(6) = T: L(6) = L: R(6) = INT(R / K * 100000 + .5) / 100000

FOR N = 1 TO 6
W$ = STR$(N)
O$ = "U" + RIGHT$(W$, LEN(W$) - 1) + ".IN"
OPEN O$ FOR OUTPUT AS 1
PRINT #1, "CM THIS DATA WAS GENERATED USING UHF.BAS 18 MARCH 98"
PRINT #1, "CM DATA IS FOR ANALYSIS USING DNEC1200 : "; O$
PRINT #1, "CE"
A$ = "GW"
B$ = ","
W = 1
S = 51
S1 = 11
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S; B$;
PRINT #1, 0; B$; 0; B$; -H2; B$; 0; B$; 0; B$; H2; B$; R2
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; T(N); B$; D; B$; 0; B$; T(N); B$; D + L(N); B$; R(N)
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; T(N); B$; -D - L(N); B$; 0; B$; T(N); B$; -D; B$; R(N)
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; -T(N); B$; D; B$; 0; B$; -T(N); B$; D + L(N); B$; R(N)
```

Antenna Products Corp.
Mineral Wells, Texas



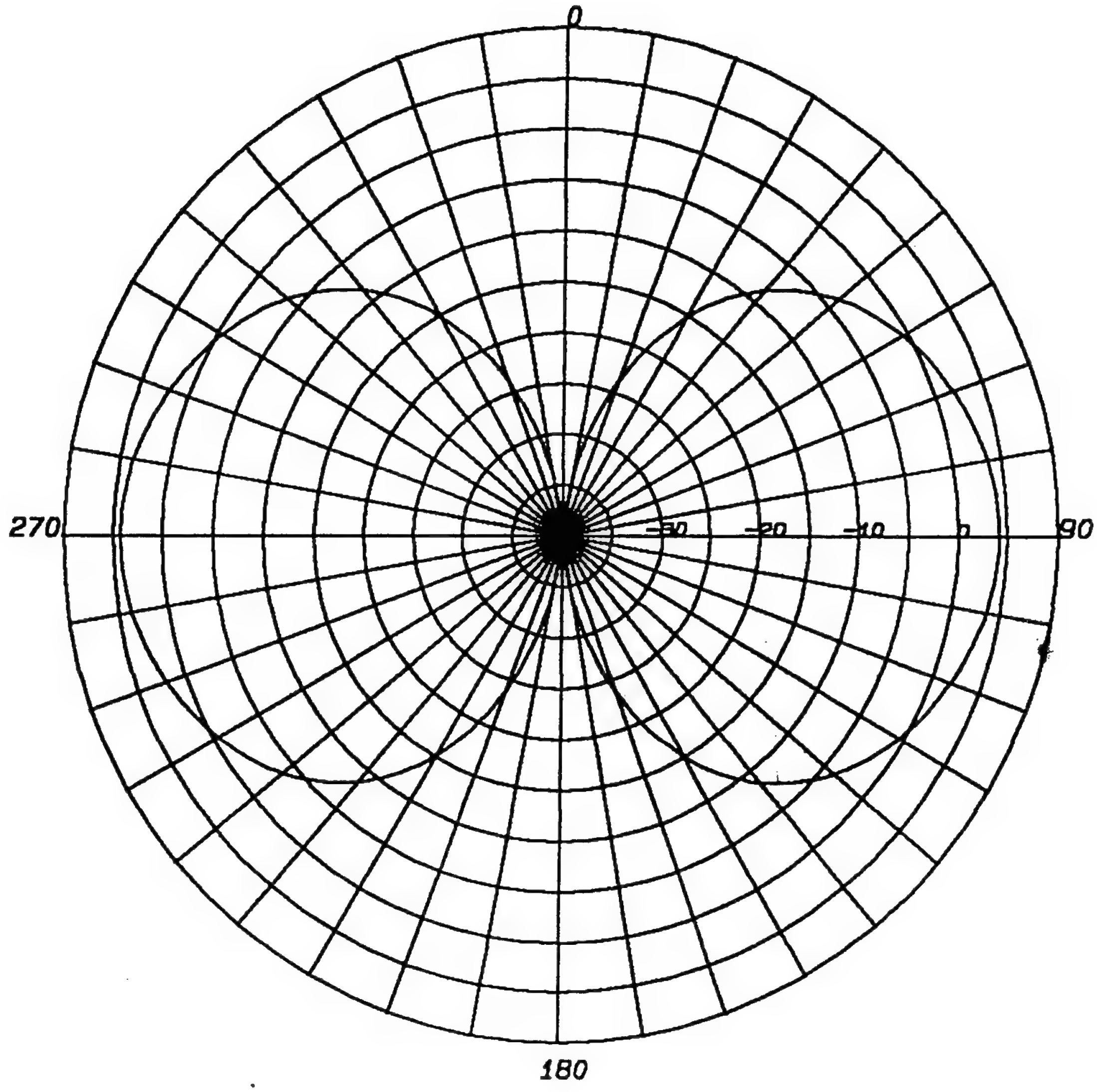
Four Dipole UHF Antenna : L = .4M
Frequency = 255 MHz : Scale is dBi
Gain = 3.8 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



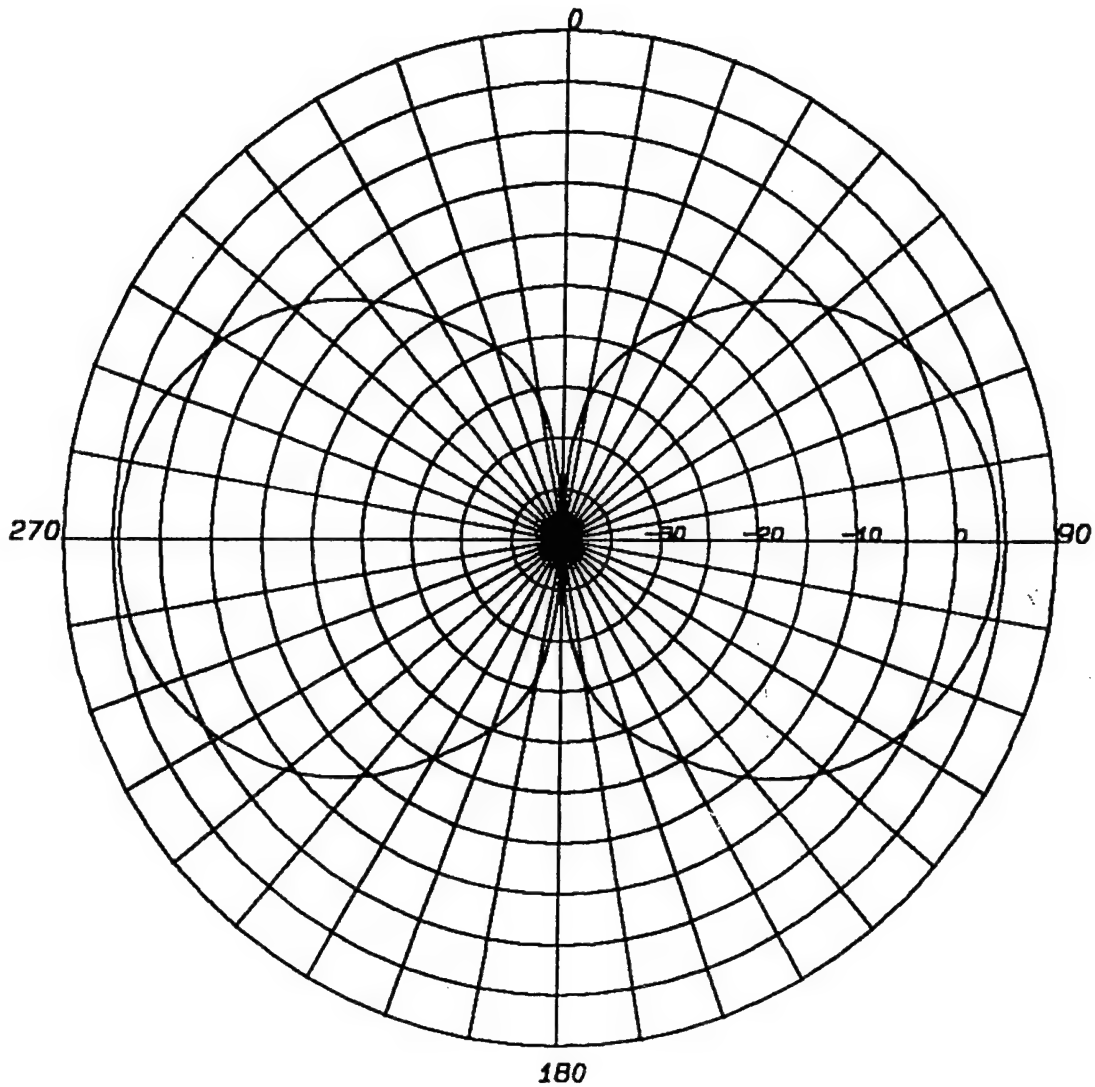
Four Dipole UHF Antenna : L = .4M
Frequency = 270 MHz : Scale is dBi
Gain = 3.97 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



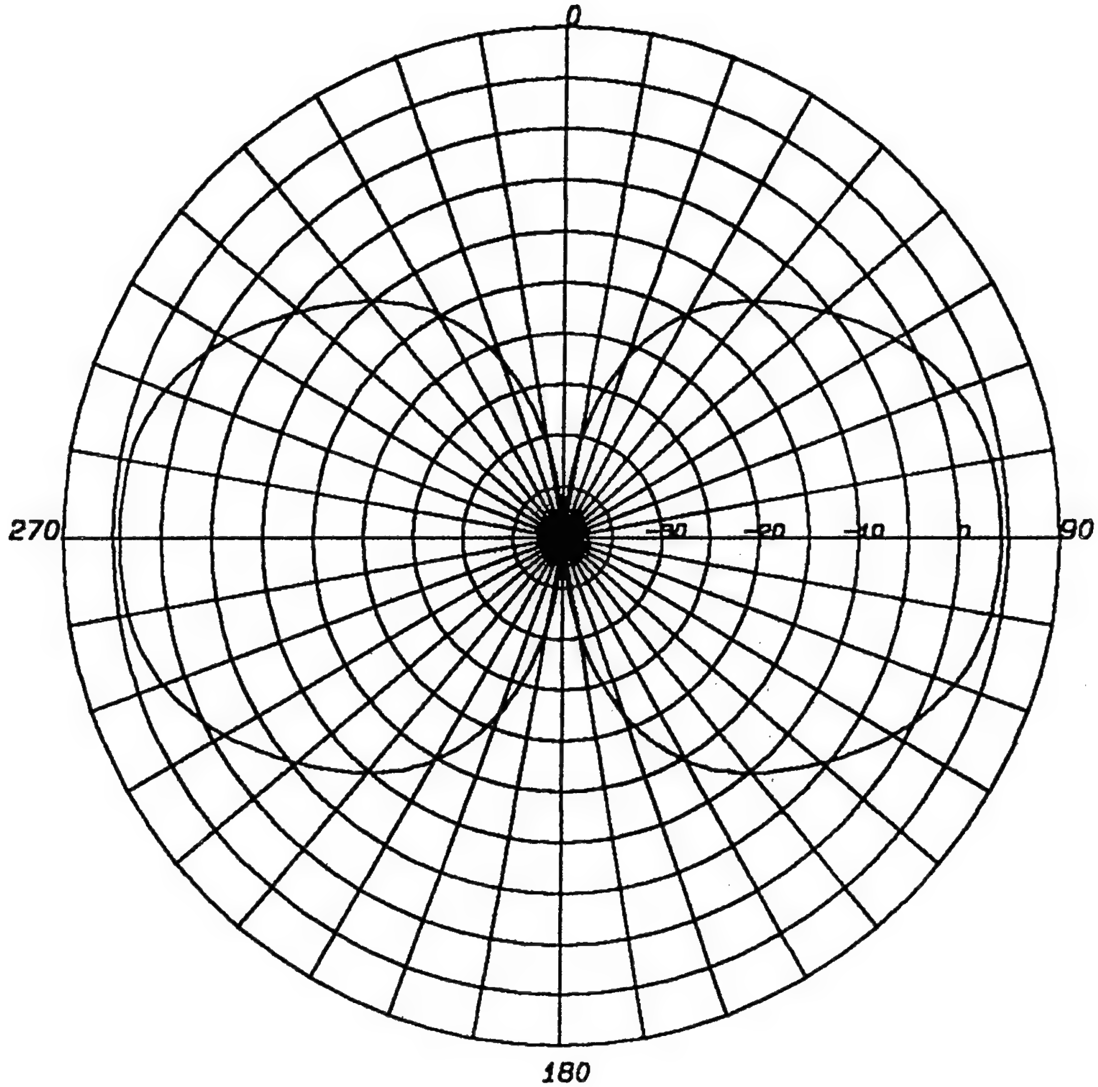
Four Dipole UHF Antenna : L = .4M
Frequency = 285 MHz : Scale is dBi
Gain = 4.17 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



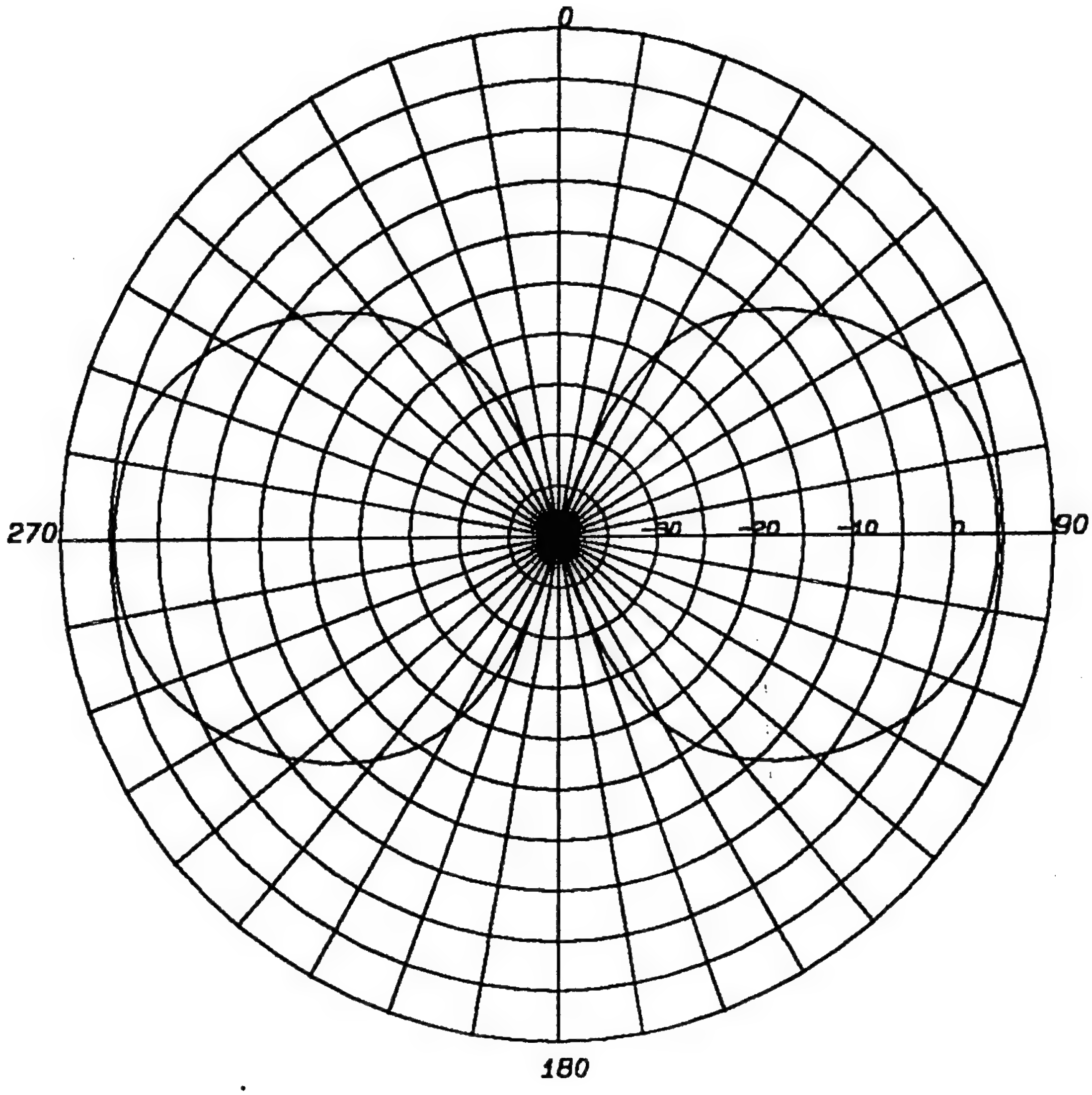
Four Dipole UHF Antenna : L = .4M
Frequency = 300 MHz : Scale is dBi
Gain = 4.26 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



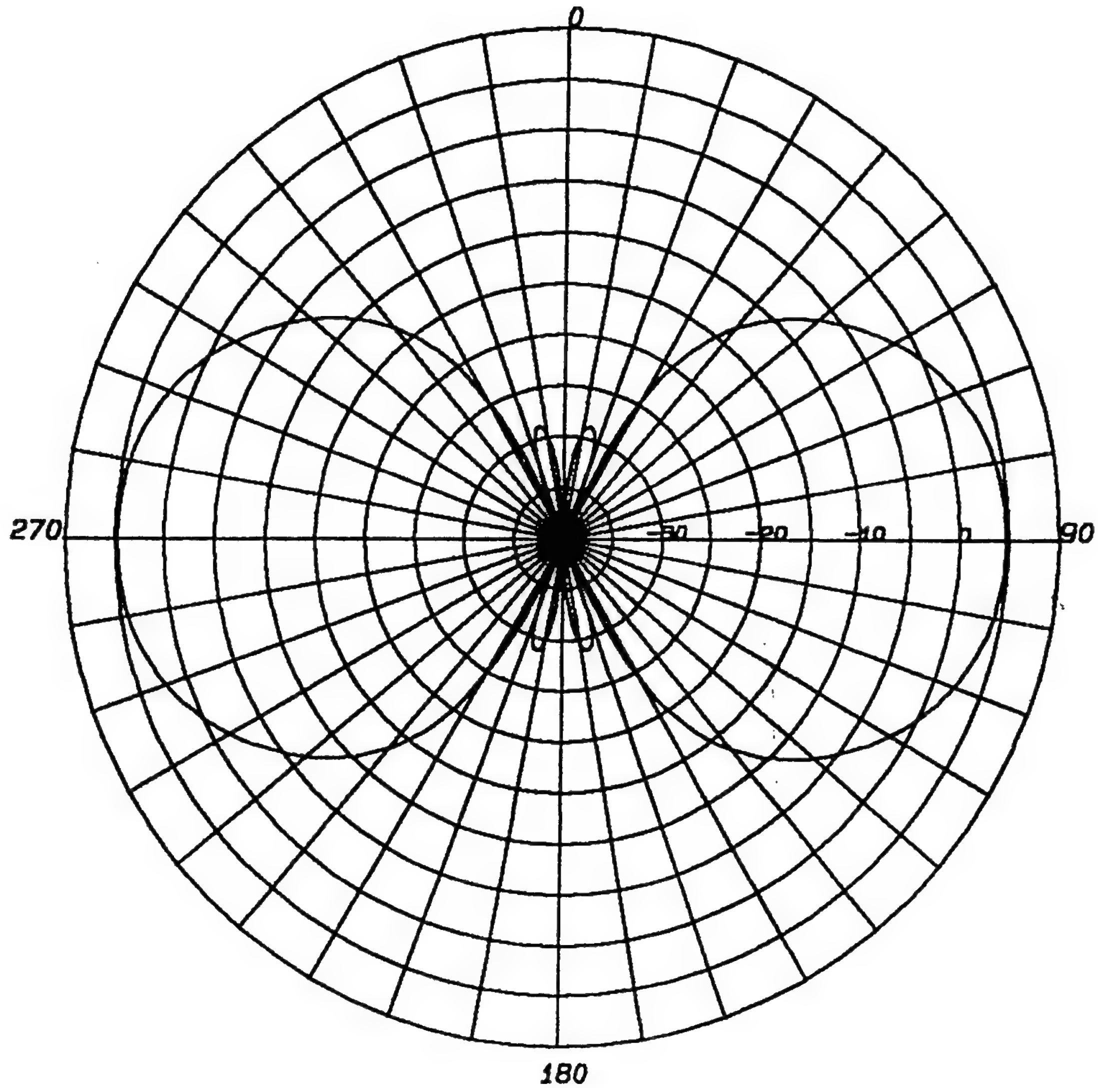
Four Dipole UHF Antenna : L = .4M
Frequency = 315 MHz : Scale is dBi
Gain = 4.25 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



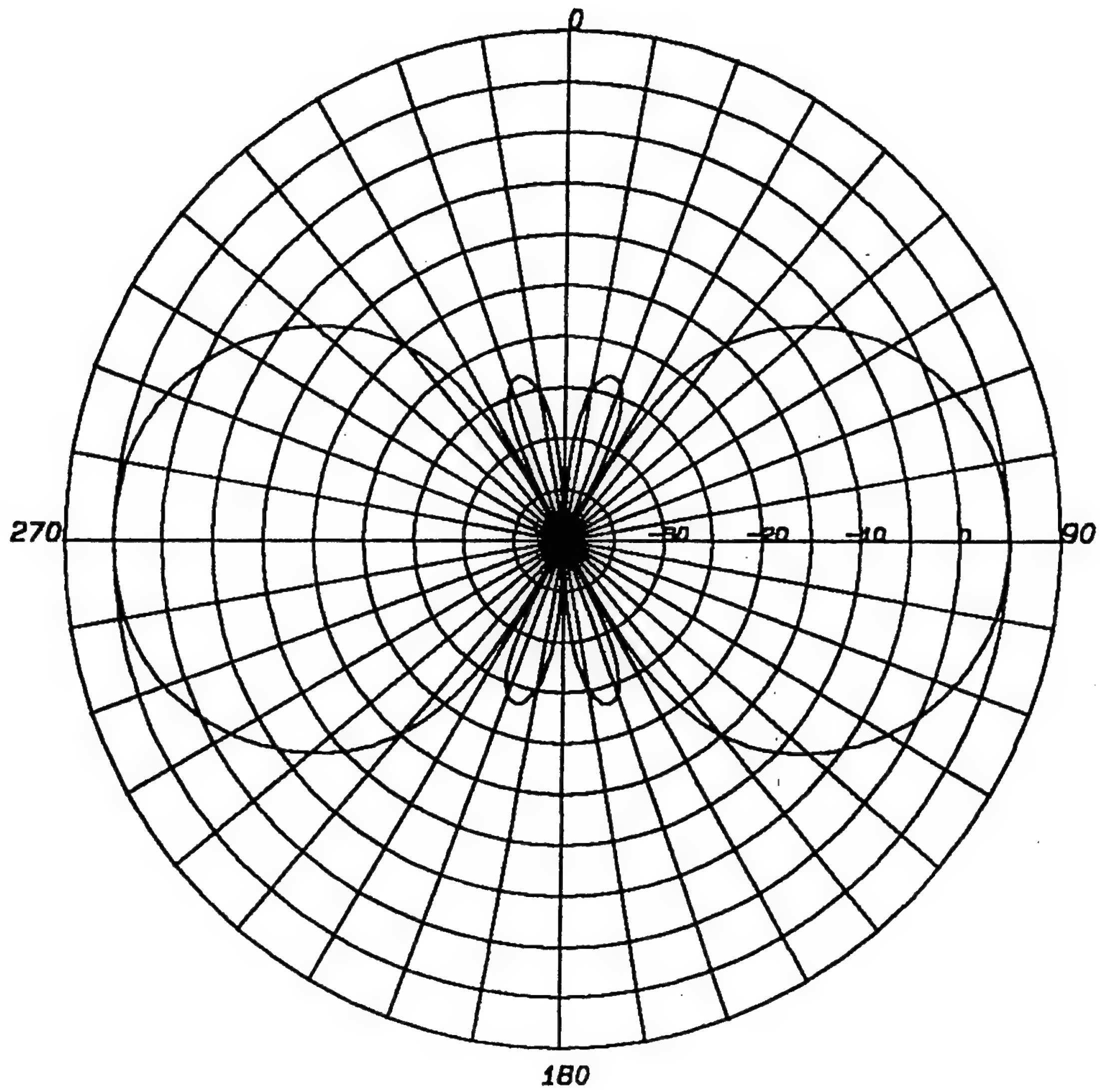
Four Dipole UHF Antenna : L = .4M
Frequency = 330 MHz : Scale is dBi
Gain = 4.5 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



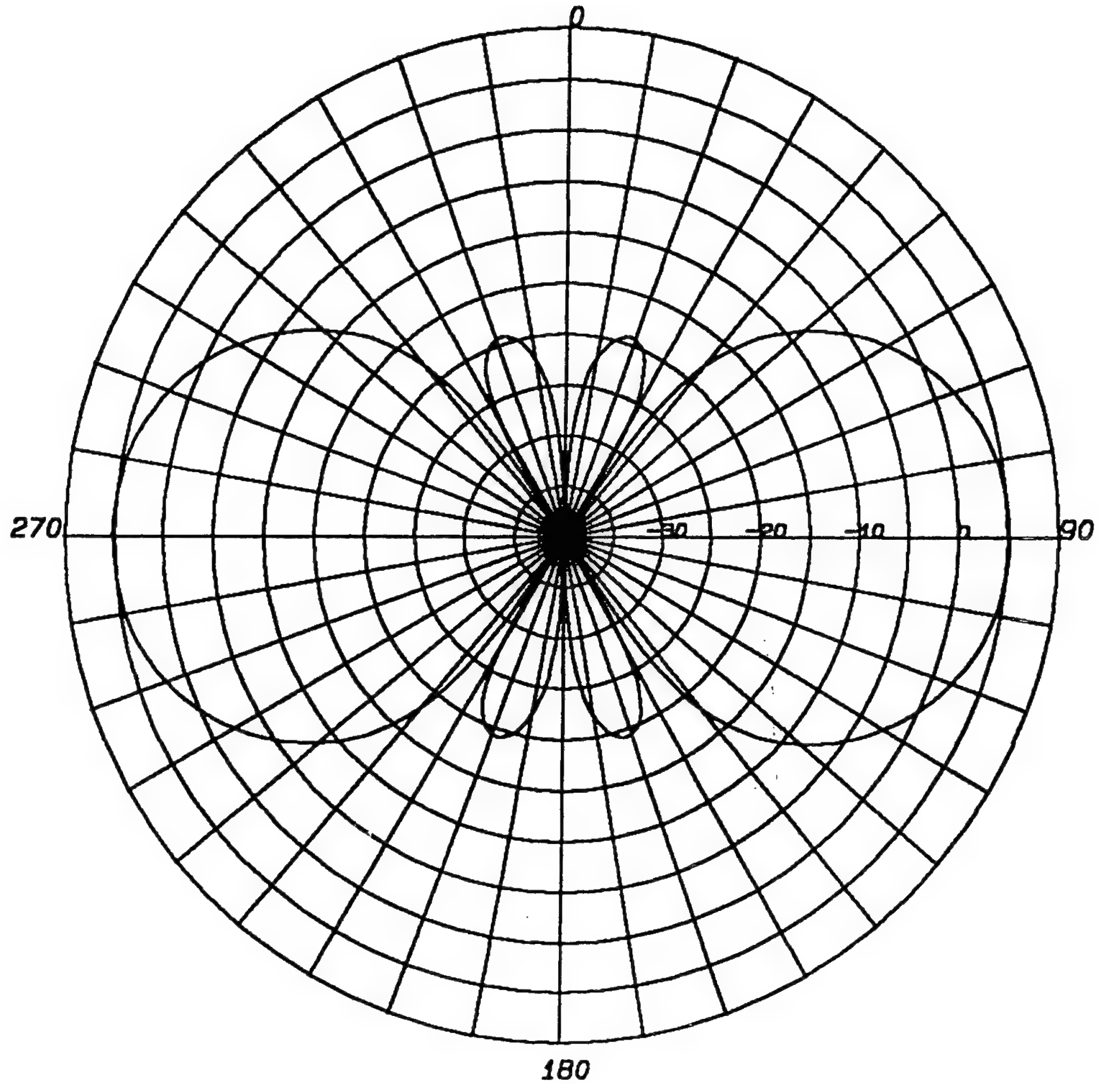
Four Dipole UHF Antenna : L = .4M
Frequency = 345 MHz : Scale is dBi
Gain = 4.7 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



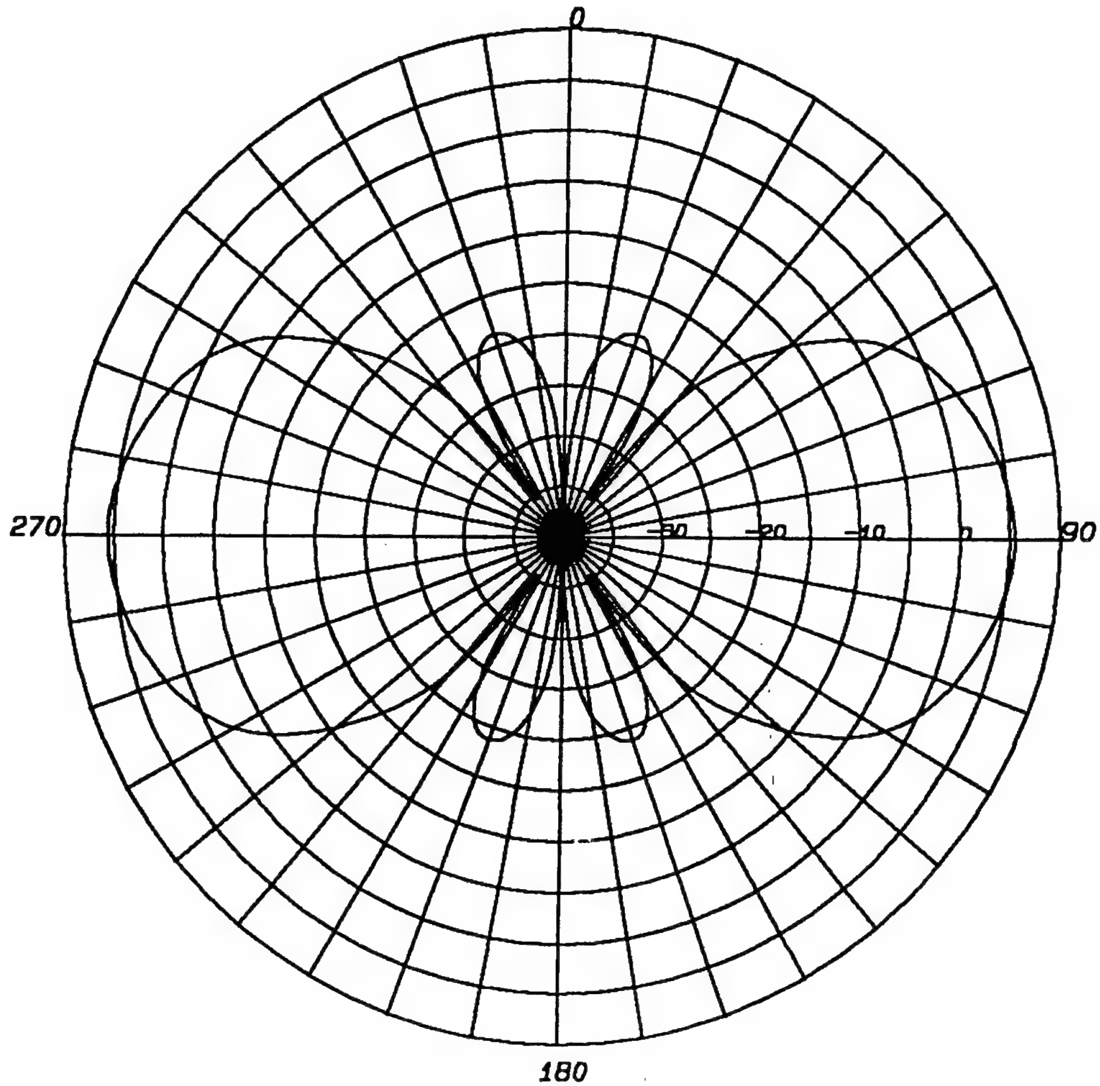
Four Dipole UHF Antenna : L = .4M
Frequency = 360 MHz : Scale is dBi
Gain = 4.89 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



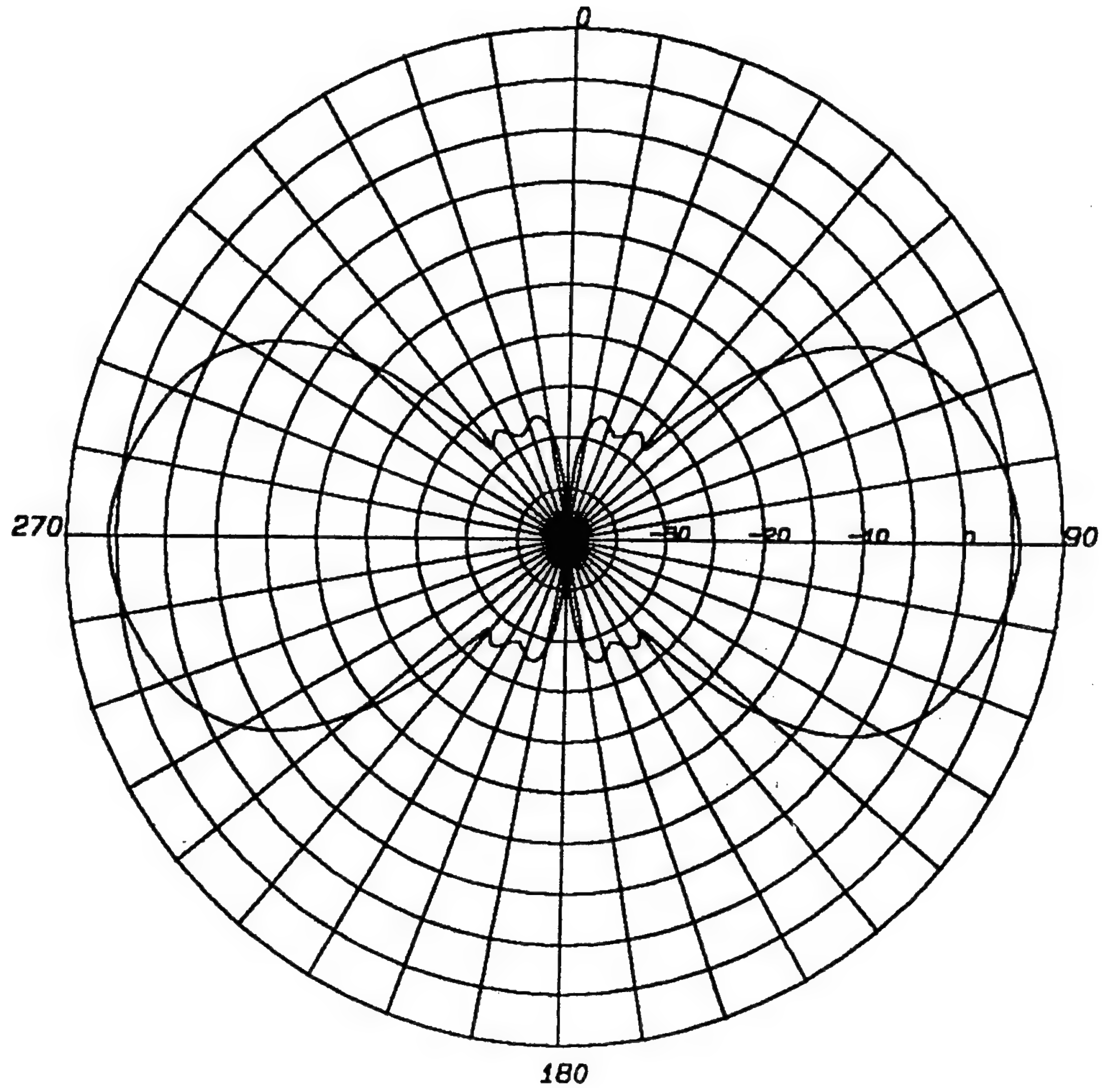
Four Dipole UHF Antenna : L = .4M
Frequency = 375 MHz : Scale is dBi
Gain = 5.08 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



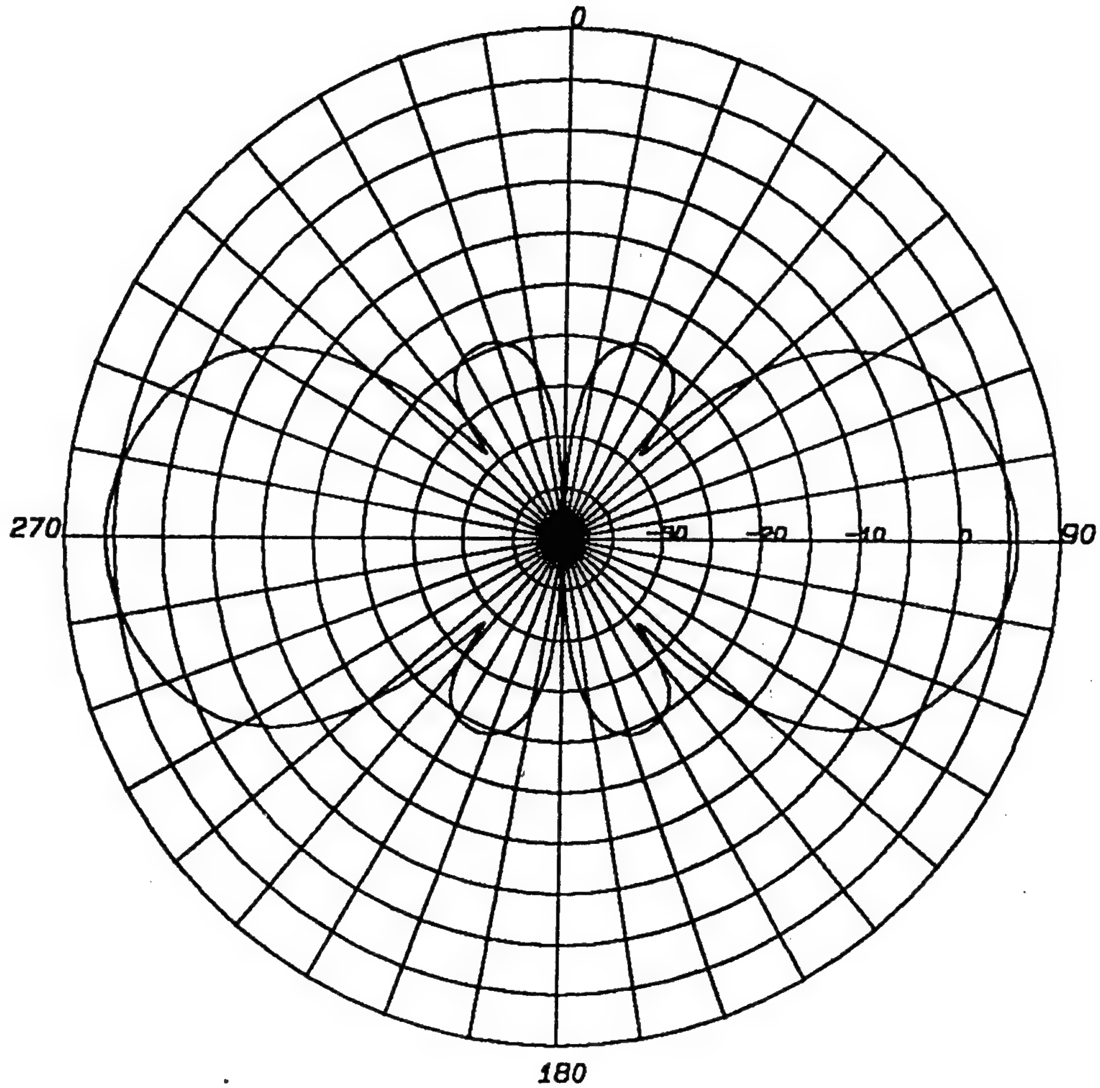
Four Dipole UHF Antenna : L = .4M
Frequency = 390 MHz : Scale is dBi
Gain = 5.47 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



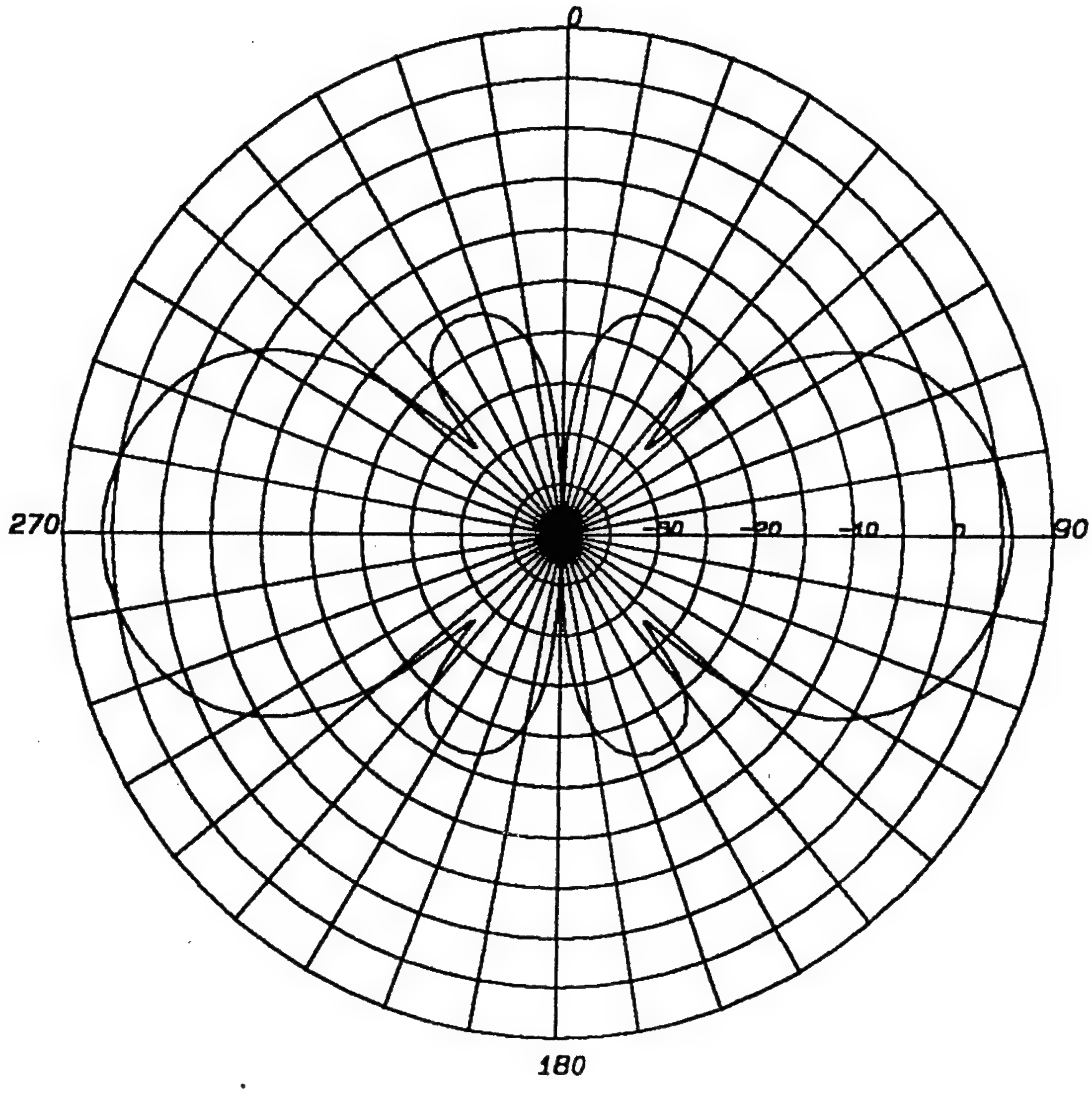
Four Dipole UHF Antenna : L = .4M
Frequency = 405 MHz : Scale is dBi
Gain = 5.67 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



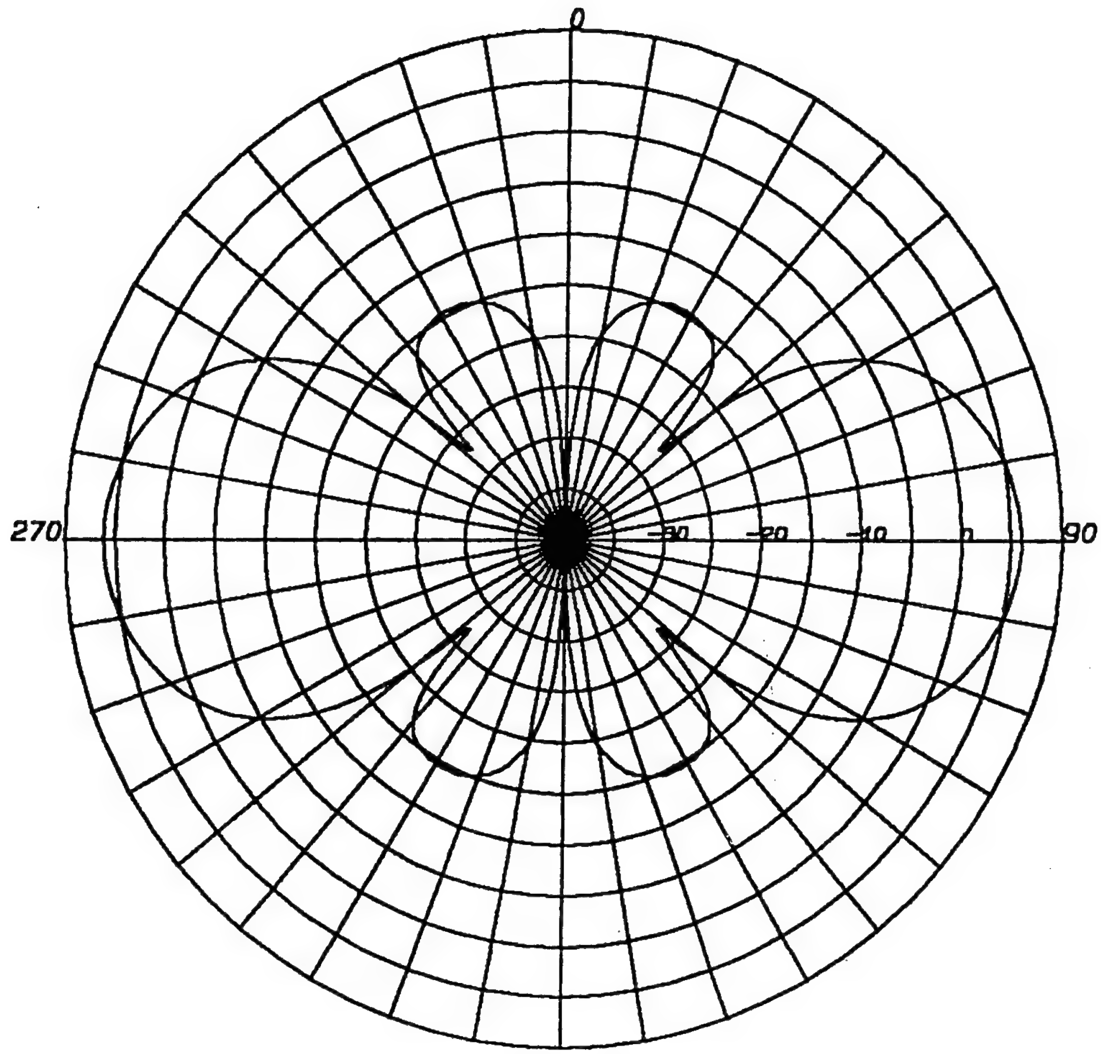
Four Dipole UHF Antenna : L = .4M
Frequency = 420 MHz : Scale is dBi
Gain = 5.75 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



Four Dipole UHF Antenna : L = .4M
Frequency = 435 MHz : Scale is dBi
Gain = 5.88 dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



Four Dipole UHF Antenna : L = .4M
Frequency = 450 MHz : Scale is dBi
Gain = 6.02 dBi : Theta = 90 Degrees

```
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; -T(N); B$; -D - L(N); B$; 0; B$; -T(N); B$; -D; B$; R(N)

REM END OF GEOMETRY CARD
A$ = "GE"
I1 = 0: I2 = 0
PRINT #1, TAB(1); A$;
PRINT #1, I1; B$; I2

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 2: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = Z0
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 3: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = Z0
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 4: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = Z0
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 5: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = Z0
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM FREQUENCY CARD (FR)
A$ = "FR"
PRINT #1, TAB(1); A$;
I1 = 1: I2 = 40
F1 = 225: F2 = K1
PRINT #1, I1; B$; I2; B$; 0; B$; 0; B$; F1; B$; F2

REM PLOT CARD (PL)
A$ = "PL"
PRINT #1, TAB(1); A$;
I1 = 4
PRINT #1, I1

REM EXECUTE CARD (XQ)
A$ = "XQ"
PRINT #1, TAB(1); A$;
I1 = 0
PRINT #1, I1

REM END CARD (EN)
A$ = "EN"
PRINT #1, TAB(1); A$

CLOSE 1
```

```
    REM CECOM AMU OPTA.BAS 06 MAR 1998 R.L. BELL
    REM THIS PROGRAM OPTIMIZES THE MATCHING CIRCUIT FOR UHF ANTENNA.

    CLS
    PI = 4 * ATN(1)
    K = .995
    DIM F(40), RA(40), XA(40)
    IP$ = "PARO.TXT"
    OPEN IP$ FOR INPUT AS 1
    INPUT #1, OFFSET, LENGTH, RADIUS
    T = OFFSET
    L = LENGTH
    R = RADIUS
    CLOSE 1

    REM ANTENNA IDENTIFIERS
    N$ = "UHFO"
    I$ = N$ + ".TXT"
    OPEN I$ FOR INPUT AS 1
    FOR Q = 1 TO 40
    INPUT #1, DUM, FREQ, REAL, IMAG, RN, XN, S
    F(Q) = FREQ
    RA(Q) = REAL
    XA(Q) = IMAG
    NEXT Q
    CLOSE 1
    GOSUB OPT

    O$ = "PARA.TXT"
    OPEN O$ FOR OUTPUT AS 3
    PRINT #3, T, L, R, N(0), SM(0), FM(0), L1(0), C1(0), L2(0), C2(0)
    CLOSE 3

    OD$ = "PARA.DOC"
    OPEN OD$ FOR OUTPUT AS 4
    PRINT #4, T, L, R, N(0), SM(0), FM(0), L1(0), C1(0), L2(0), C2(0)
    CLOSE 4
    END

OPT: REM START OPTIMIZER PROGRAM FOR MATCHING ANTENNA IMPEDANCES
    L1 = .3                           ' MICROHENRIES
    C1 = 10                          ' PICOFARADS
    C2 = 5                           ' PICOFARADS
    L2 = .2                          ' MICROHENRIES
    REM L1 IS A SHUNT INDUCTANCE NEXT TO ANTENNA.
    REM C1 IS A SERIES CAPACITANCE.
    REM C2 IS A SHUNT CAPACITANCE.
    REM L2 IS A SERIES INDUCTANCE.

    EX = 10
    ZO = 100
HERE:
    GOSUB CAL
    NO = S1: SM0 = SM: FM0 = FM: L1 = L1 * K: GOSUB CAL
    N1 = S1: SM1 = SM: FM1 = FM: L1 = L1 / K: C1 = C1 * K: GOSUB CAL
    N2 = S1: SM2 = SM: FM2 = FM: C1 = C1 / K: L2 = L2 * K: GOSUB CAL
    N3 = S1: SM3 = SM: FM3 = FM: L2 = L2 / K: C2 = C2 * K: GOSUB CAL
    N4 = S1: SM4 = SM: FM4 = FM: C2 = C2 / K: L1 = L1 / K: GOSUB CAL
    N5 = S1: SM5 = SM: FM5 = FM: L1 = L1 * K: C1 = C1 / K: GOSUB CAL
    N6 = S1: SM6 = SM: FM6 = FM: C1 = C1 * K: L2 = L2 / K: GOSUB CAL
    N7 = S1: SM7 = SM: FM7 = FM: L2 = L2 * K: C2 = C2 / K: GOSUB CAL
    N8 = S1: SM8 = SM: FM8 = FM: C2 = C2 * K

    M1 = NO - N1: M2 = NO - N2: M3 = NO - N3: M4 = NO - N4
    M5 = NO - N5: M6 = NO - N6: M7 = NO - N7: M8 = NO - N8

    IF M2 > M1 GOTO 413
```

```
    IF M3 > M1 GOTO 419
    IF M4 > M1 GOTO 424
    IF M5 > M1 GOTO 428
    IF M6 > M1 GOTO 432
    IF M7 > M1 GOTO 436
    IF M8 > M1 GOTO 440
    IF M1 < 0 THEN GOTO 600
    L1 = L1 * K
    GOTO HERE
413 IF M3 > M2 GOTO 419
    IF M4 > M2 GOTO 424
    IF M5 > M2 GOTO 428
    IF M6 > M2 GOTO 432
    IF M7 > M2 GOTO 436
    IF M8 > M2 GOTO 440
    IF M2 < 0 THEN GOTO 600
    C1 = C1 * K
    GOTO HERE
419 IF M4 > M3 GOTO 424
    IF M5 > M3 GOTO 428
    IF M6 > M3 GOTO 432
    IF M7 > M3 GOTO 436
    IF M8 > M3 GOTO 440
    IF M3 < 0 THEN GOTO 600
    L2 = L2 * K
    GOTO HERE
424 IF M5 > M4 GOTO 428
    IF M6 > M4 GOTO 432
    IF M7 > M4 GOTO 436
    IF M8 > M4 GOTO 440
    IF M4 < 0 THEN GOTO 600
    C2 = C2 * K
    GOTO HERE
  8 IF M6 > M5 GOTO 432
    IF M7 > M5 GOTO 436
    IF M8 > M5 GOTO 440
    IF M5 < 0 THEN GOTO 600
    L1 = L1 / K
    GOTO HERE
432 IF M7 > M6 GOTO 436
    IF M8 > M6 GOTO 440
    IF M6 < 0 THEN GOTO 600
    C1 = C1 / K
    GOTO HERE
436 IF M8 > M7 GOTO 440
    IF M7 < 0 THEN GOTO 600
    L2 = L2 / K
    GOTO HERE
440 IF M8 < 0 THEN GOTO 600
    C2 = C2 / K
    GOTO HERE
600 L1(0) = INT(L1 * 10000 + .5) / 10000
    C1(0) = INT(C1 * 10000 + .5) / 10000
    L2(0) = INT(L2 * 10000 + .5) / 10000
    C2(0) = INT(C2 * 10000 + .5) / 10000
    N(0) = NO
    SM(0) = SMO
    FM(0) = FMO
    RETURN

[illegible]L:
    S1 = 0: SM = 0
    FOR Q = 1 TO 40
    DA = RA(Q) ^ 2 + XA(Q) ^ 2
    GA = RA(Q) / DA
    BA = -XA(Q) / DA
    XL1 = 2 * PI * F(Q) * L1
```

```
BL1 = -1 / XL1
G1 = GA
B1 = BA + BL1
D1 = G1 ^ 2 + B1 ^ 2
R1 = G1 / D1
X1 = -B1 / D1
XC1 = -159000 / F(Q) / C1
R2 = R1
X2 = X1 + XC1
D2 = R2 ^ 2 + X2 ^ 2
G2 = R2 / D2
B2 = -X2 / D2
XC2 = -159000 / F(Q) / C2
BC2 = -1 / XC2
G3 = G2
B3 = B2 + BC2
D3 = G3 ^ 2 + B3 ^ 2
R3 = G3 / D3
X3 = -B3 / D3
XL2 = 2 * PI * F(Q) * L2
RI = R3
XI = X3 + XL2
DP = (RI + Z0) ^ 2 + XI ^ 2
RP = (RI ^ 2 - Z0 ^ 2 + XI ^ 2) / DP
IP = (2 * XI * Z0) / DP
P = SQR(RP ^ 2 + IP ^ 2)
S = (1 + P) / (1 - P)
IF SM < S THEN SM = S: FM = F(Q)
S1 = S1 + S ^ EX
NEXT Q
RETURN
```

```
CLS
COLOR 2
PI = 4 * ATN(1)
DIM X(50), Y(50), Z(50), A(50)
REM UHF.BAS : 18 MARCH 1998 : ROSS L. BELL
REM THIS PROGRAM IS TO GENERATE INPUT DATA FOR NEC3
REM UHF & VHF DIPOLE COMBINATION ANTENNA.
FL = 225
FH = 450
REM L = .4                              'LENGTH OF UHF DIPOLE
REM R = .00625                          'RADIUS OF UHF DIPOLE
R2 = .025                               'RADIUS OF VHF DIPOLE
L2 = 1.68                               'LENGTH OF VHF DIPOLE
REM T = .05                             'OFF-SET OF UHF DIPOLE Y-DIR
D = .05                                 'OFF-SET OF UHF DIPOLES Z-DIR
K = .995                                'SCALING FACTOR
NF = 40                                 'NUMBER OF FREQUENCIES
TAU = EXP(LOG(FL / FH) / (NF - 1))
K1 = 1 / TAU                            'FREQUENCY SCALE

I$ = "PARA.TXT"
OPEN I$ FOR INPUT AS 1
PRINT #1, T(0), L(0), R(0), N, SM, FM, L1, C1, L2, C2
T = INT(T(0) * 10000 + .5) / 10000
L = INT(L(0) * 10000 + .5) / 10000
R = INT(R(0) * 10000 + .5) / 10000
CLOSE 1
T(1) = INT(T * K * 10000 + .5) / 10000: L(1) = L: R(1) = R
T(2) = INT(T / K * 10000 + .5) / 10000: L(2) = L: R(2) = R
T(3) = T: L(3) = INT(L * K * 10000 + .5) / 10000: R(3) = R
T(4) = T: L(4) = INT(L / K * 10000 + .5) / 10000: R(4) = R
T(5) = T: L(5) = L: R(5) = INT(R * K * 10000 + .5) / 10000
T(6) = T: L(6) = L: R(6) = INT(R / K * 10000 + .5) / 10000

FOR W = 1 TO 6
W$ = STR$(W)
O$ = "UHF" + RIGHT$(W$, LEN(W$) - 1) + ".IN"
OPEN O$ FOR OUTPUT AS 1
PRINT #1, "CM THIS DATA WAS GENERATED USING UHF.BAS 18 MARCH 98"
PRINT #1, "CM DATA IS FOR ANALYSIS USING DNEC1200"; O$
PRINT #1, "CE"
A$ = "GW"
B$ = ","
W = 1
S = 51
S1 = 11
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S; B$;
PRINT #1, 0; B$; 0; B$; -L2; B$; 0; B$; 0; B$; L2; B$; R2
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; T(W); B$; D; B$; 0; B$; T(W); B$; D + L(W); B$; R(W)
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; T(W); B$; -D - L(W); B$; 0; B$; T(W); B$; -D; B$; R(W)
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; -T(W); B$; D; B$; 0; B$; -T(W); B$; D + L(W); B$; R(W)
W = W + 1
PRINT #1, TAB(1); A$;
PRINT #1, W; B$; S1; B$;
PRINT #1, 0; B$; -T(W); B$; -D - L(W); B$; 0; B$; -T(W); B$; -D; B$; R(W)
```

```
REM END OF GEOMETRY CARD
A$ = "GE"
I1 = 0: I2 = 0
PRINT #1, TAB(1); A$;
PRINT #1, I1; B$; I2

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 2: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = 100
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 3: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = 100
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 4: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = 100
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM EXCITATION CARD
A$ = "EX"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 5: I3 = 6: I4 = 11
F1 = 100: F2 = 0: F3 = 100
PRINT #1, I1; B$; I2; B$; I3; B$; I4; B$; F1; B$; F2; B$; F3

REM FREQUENCY CARD (FR)
A$ = "FR"
PRINT #1, TAB(1); A$;
I1 = 0: I2 = 40
F1 = 225: F2 = K1
PRINT #1, I1; B$; I2; B$; 0; B$; 0; B$; F1; B$; F2

REM PLOT CARD (PL)
A$ = "PL"
PRINT #1, TAB(1); A$;
I1 = 4
PRINT #1, I1

REM EXECUTE CARD (XQ)
A$ = "XQ"
PRINT #1, TAB(1); A$;
I1 = 0
PRINT #1, I1

REM END CARD (EN)
A$ = "EN"
PRINT #1, TAB(1); A$

CLOSE 1
NEXT W
END
```

```
START: REM OPT.BAS 18 MARCH 1998 R.L. BELL
    PI = 4 * ATN(1): K = .995
    PRINT "THIS PROGRAM OPTIMIZES THE ANTENNA PARAMETERS FOR"
    PRINT "THE UHF ANTENNA USING NEC-3 OUTPUT IMPEDANCES"
    DIM F(40), RA(40), XA(40)
    DIM T(10), L(10), R(10), N(10), SM(10), FM(10)
    DIM L1(10), C1(10), L2(10), C2(10)
    DIM T0(100), L0(100), R0(100), N0(100), SM0(100), FM0(100)
    DIM L10(100), C10(100), L20(100), C20(100)

    I$ = "PARA.TXT"
    OPEN I$ FOR INPUT AS 1
    INPUT #1, T, L, R, SN, SM, FM, L1, C1, L2, C2
    T(0) = T
    L(0) = L
    R(0) = R
    N(0) = SN
    SM(0) = SM
    FM(0) = FM
    L1(0) = L1
    C1(0) = C1
    L2(0) = L2
    C2(0) = C2
    CLOSE 1

    FOR P = 1 TO 4
    P$ = STR$(P)
    F$ = "UHF" + RIGHT$(P$, LEN(P$) - 1) + ".TXT"
    OPEN F$ FOR INPUT AS 2
    FOR Q = 1 TO 40
    INPUT #2, DUM1, F, RI, XI, RN, XN, VSWR
    F(Q) = F
    RA(Q) = RI
    XA(Q) = XI
    NEXT Q
    CLOSE 2
    L1 = L1(0)
    C1 = C1(0)
    L2 = L2(0)
    C2 = C2(0)
    GOSUB OPT
    NEXT P

    M1 = N(0) - N(1): M2 = N(0) - N(2): M3 = N(0) - N(3)
    M4 = N(0) - N(4): M5 = N(0) - N(5): M6 = N(0) - N(6)

    IF M2 > M1 GOTO 413
    IF M3 > M1 GOTO 419
    IF M4 > M1 GOTO 424
    IF M5 > M1 GOTO 428
    IF M6 > M1 GOTO 432
    IF M1 < 0 GOTO 500
    T(0) = T(0) * K
    N(0) = N(1): SM(0) = SM(1): FM(0) = F(1)
    L1(0) = L1(1): C1(0) = C1(1): L2(0) = L2(1): C2(0) = C2(1)
    GOTO HERE
413 IF M3 > M2 GOTO 419
    IF M4 > M2 GOTO 424
    IF M5 > M2 GOTO 428
    IF M6 > M2 GOTO 432
    IF M2 < 0 GOTO 500
    T(0) = T(0) / K
    N(0) = N(2): SM(0) = SM(2): FM(0) = F(2)
    L1(0) = L1(2): C1(0) = C1(2): L2(0) = L2(2): C2(0) = C2(2)
    GOTO HERE
419 IF M4 > M3 GOTO 424
    IF M5 > M3 GOTO 428
```

```
    IF M6 > M3 GOTO 432
    IF M3 < 0 GOTO 500
    L(0) = L(0) * K
    N(0) = N(3): SM(0) = SM(3): FM(0) = F(3)
    L1(0) = L1(3): C1(0) = C1(3): L2(0) = L2(3): C2(0) = C2(3)
    GOTO HERE
  4 IF M5 > M4 GOTO 428
    IF M6 > M4 GOTO 432
    IF M4 < 0 GOTO 500
    L(0) = L(0) / K
    N(0) = N(4): SM(0) = SM(4): FM(0) = F(4)
    L1(0) = L1(4): C1(0) = C1(4): L2(0) = L2(4): C2(0) = C2(4)
    GOTO HERE
428 IF M6 > M5 GOTO 432
    IF M5 < 0 GOTO 500
    R(0) = R(0) * K
    N(0) = N(5): SM(0) = SM(5): FM(0) = F(5)
    L1(0) = L1(5): C1(0) = C1(5): L2(0) = L2(5): C2(0) = C2(5)
    GOTO HERE
432 IF M6 < 0 GOTO 500
    R(0) = R(0) / K
    N(0) = N(6): SM(0) = SM(6): FM(0) = F(6)
    L1(0) = L1(6): C1(0) = C1(6): L2(0) = L2(6): C2(0) = C2(6)
    GOTO HERE

500
    P$ = "P.TXT"
    OPEN P$ FOR OUTPUT AS 4
    PRINT #4, "Offset = "; INT(10000 * T(0) + .5) / 10000; " Meters"
    PRINT #4, "Length = "; INT(10000 * L(0) + .5) / 10000; " Meters"
    PRINT #4, "Radius = "; INT(10000 * R(0) + .5) / 10000; " Meters"
    PRINT #4, "Quality Factor = "; N(0)
    PRINT #4, "Maximum VSWR = "; SM(0)
    PRINT #4, "Frequency = "; FM(0); " Mhz"
    PRINT #4, "L1 = "; INT(L1(0) * 10000 + .5) / 10000; " Microhenrys"
    PRINT #4, "C1 = "; INT(C1(0) * 10000 + .5) / 10000; " Picofarads"
    PRINT #4, "L2 = "; INT(L2(0) * 10000 + .5) / 10000; " Microhenrys"
    PRINT #4, "C2 = "; INT(C2(0) * 10000 + .5) / 10000; " Picofarads"
    CLOSE 4

HERE:
    O$ = "PARA.TXT"
    OPEN O$ FOR OUTPUT AS 3
    PRINT #3, T(0), L(0), R(0), N(0), SM(0), FM(0), L1(0), C1(0), L2(0), C2(0)
    CLOSE 3
    Q = 0
    OD$ = "PARA.DOC"
    OPEN OD$ FOR INPUT AS 5
    WHILE NOT EOF(5)
    Q = Q + 1
    PRINT #5, T, L, R, N, SM, FM, L1, C1, L2, C2
    T0(Q) = T
    L0(Q) = L
    R0(Q) = R
    N0(Q) = N
    SM0(Q) = SM
    FM0(Q) = FM
    L10(Q) = L1
    C10(Q) = C1
    L20(Q) = L2
    C20(Q) = C2
    WEND
    CLOSE 5

    T0(Q + 1) = T(0)
    L0(Q + 1) = L(0)
    R0(Q + 1) = R(0)
```

```
    N0(Q + 1) = N(0)
    SM0(Q + 1) = SM(0)
    FM0(Q + 1) = FM(0)
    L10(Q + 1) = L1(0)
    C10(Q + 1) = C1(0)
    L20(Q + 1) = L2(0)
    C20(Q + 1) = C2(0)

    OPEN OD$ FOR OUTPUT AS 6
    FOR QK = 1 TO Q + 1
    PRINT #6, T(QK), L(QK), R(QK), N(QK), SM(QK), FM(QK);
    PRINT #6, L1(QK), C1(QK), L2(QK), C2(QK)
    NEXT QK
    CLOSE 6
    END

OPT: Z0 = 100: EX = 10
AMU: GOSUB CAL
    N0 = S1: SM0 = SM: FM0 = FM: L1 = L1 * K: GOSUB CAL
    N1 = S1: SM1 = SM: FM1 = FM: L1 = L1 / K: C1 = C1 * K: GOSUB CAL
    N2 = S1: SM2 = SM: FM2 = FM: C1 = C1 / K: L2 = L2 * K: GOSUB CAL
    N3 = S1: SM3 = SM: FM3 = FM: L2 = L2 / K: C2 = C2 * K: GOSUB CAL
    N4 = S1: SM4 = SM: FM4 = FM: C2 = C2 / K: L1 = L1 / K: GOSUB CAL
    N5 = S1: SM5 = SM: FM5 = FM: L1 = L1 * K: C1 = C1 / K: GOSUB CAL
    N6 = S1: SM6 = SM: FM6 = FM: C1 = C1 * K: L2 = L2 / K: GOSUB CAL
    N7 = S1: SM7 = SM: FM7 = FM: L2 = L2 * K: C2 = C2 / K: GOSUB CAL
    N8 = S1: SM8 = SM: FM8 = FM: C2 = C2 * K

    M1 = N0 - N1: M2 = N0 - N2: M3 = N0 - N3: M4 = N0 - N4
    M5 = N0 - N5: M6 = N0 - N6: M7 = N0 - N7: M8 = N0 - N8

    IF M2 > M1 GOTO 1413
    IF M3 > M1 GOTO 1419
    IF M4 > M1 GOTO 1424
    IF M5 > M1 GOTO 1428
    IF M6 > M1 GOTO 1432
    IF M7 > M1 GOTO 1436
    IF M8 > M1 GOTO 1440
    IF M1 < 0 THEN GOTO 1600
    L1 = L1 * K
    GOTO AMU
1413 IF M3 > M2 GOTO 1419
    IF M4 > M2 GOTO 1424
    IF M5 > M2 GOTO 1428
    IF M6 > M2 GOTO 1432
    IF M7 > M2 GOTO 1436
    IF M8 > M2 GOTO 1440
    IF M2 < 0 THEN GOTO 1600
    C1 = C1 * K
    GOTO AMU
1419 IF M4 > M3 GOTO 1424
    IF M5 > M3 GOTO 1428
    IF M6 > M3 GOTO 1432
    IF M7 > M3 GOTO 1436
    IF M8 > M3 GOTO 1440
    IF M3 < 0 THEN GOTO 1600
    L2 = L2 * K
    GOTO AMU
1424 IF M5 > M4 GOTO 1428
    IF M6 > M4 GOTO 1432
    IF M7 > M4 GOTO 1436
    IF M8 > M4 GOTO 1440
    IF M4 < 0 THEN GOTO 1600
    C2 = C2 * K
    GOTO AMU
1428 IF M6 > M5 GOTO 1432
    IF M7 > M5 GOTO 1436
```

```
    IF M8 > M5 GOTO 1440
    IF M5 < 0 THEN GOTO 1600
    L1 = L1 / K
    GOTO AMU
1432 IF M7 > M6 GOTO 1436
    IF M8 > M6 GOTO 1440
    IF M6 < 0 THEN GOTO 1600
    C1 = C1 / K
    GOTO AMU
1436 IF M8 > M7 GOTO 1440
    IF M7 < 0 THEN GOTO 1600
    L2 = L2 / K
    GOTO AMU
1440 IF M8 < 0 THEN GOTO 1600
    C2 = C2 / K
    GOTO AMU
1600 L1(P) = INT(L1 * 10000 + .5) / 10000
    C1(P) = INT(C1 * 10000 + .5) / 10000
    L2(P) = INT(L2 * 10000 + .5) / 10000
    C2(P) = INT(C2 * 10000 + .5) / 10000
    N(P) = NO
    SM(P) = SM0
    FM(P) = FM0
    RETURN

CAL:
    S1 = 0: SM = 0
    FOR Q = 1 TO 40
    DA = RA(Q) ^ 2 + XA(Q) ^ 2
    GA = RA(Q) / DA
    BA = -XA(Q) / DA
    XL1 = 2 * PI * F(Q) * L1
    BL1 = -1 / XL1
    G1 = GA
    B1 = BA + BL1
    D1 = G1 ^ 2 + B1 ^ 2
    R1 = G1 / D1
    X1 = -B1 / D1
    XC1 = -159000 / F(Q) / C1
    R2 = R1
    X2 = X1 + XC1
    D2 = R2 ^ 2 + X2 ^ 2
    G2 = R2 / D2
    B2 = -X2 / D2
    XC2 = -159000 / F(Q) / C2
    BC2 = -1 / XC2
    G3 = G2
    B3 = B2 + BC2
    D3 = G3 ^ 2 + B3 ^ 2
    R3 = G3 / D3
    X3 = -B3 / D3
    XL2 = 2 * PI * F(Q) * L2
    RI = R3
    XI = X3 + XL2
    DP = (RI + Z0) ^ 2 + XI ^ 2
    RP = (RI ^ 2 - Z0 ^ 2 + XI ^ 2) / DP
    IP = (2 * XI * Z0) / DP
    P = SQR(RP ^ 2 + IP ^ 2)
    S = (1 + P) / (1 - P)
    IF SM < S THEN SM = S: FM = F(Q)
    S1 = S1 + S ^ EX
    NEXT Q
    RETURN
```

APPENDIX F
E-Plane Patterns for the UHF Antenna of Configuration C

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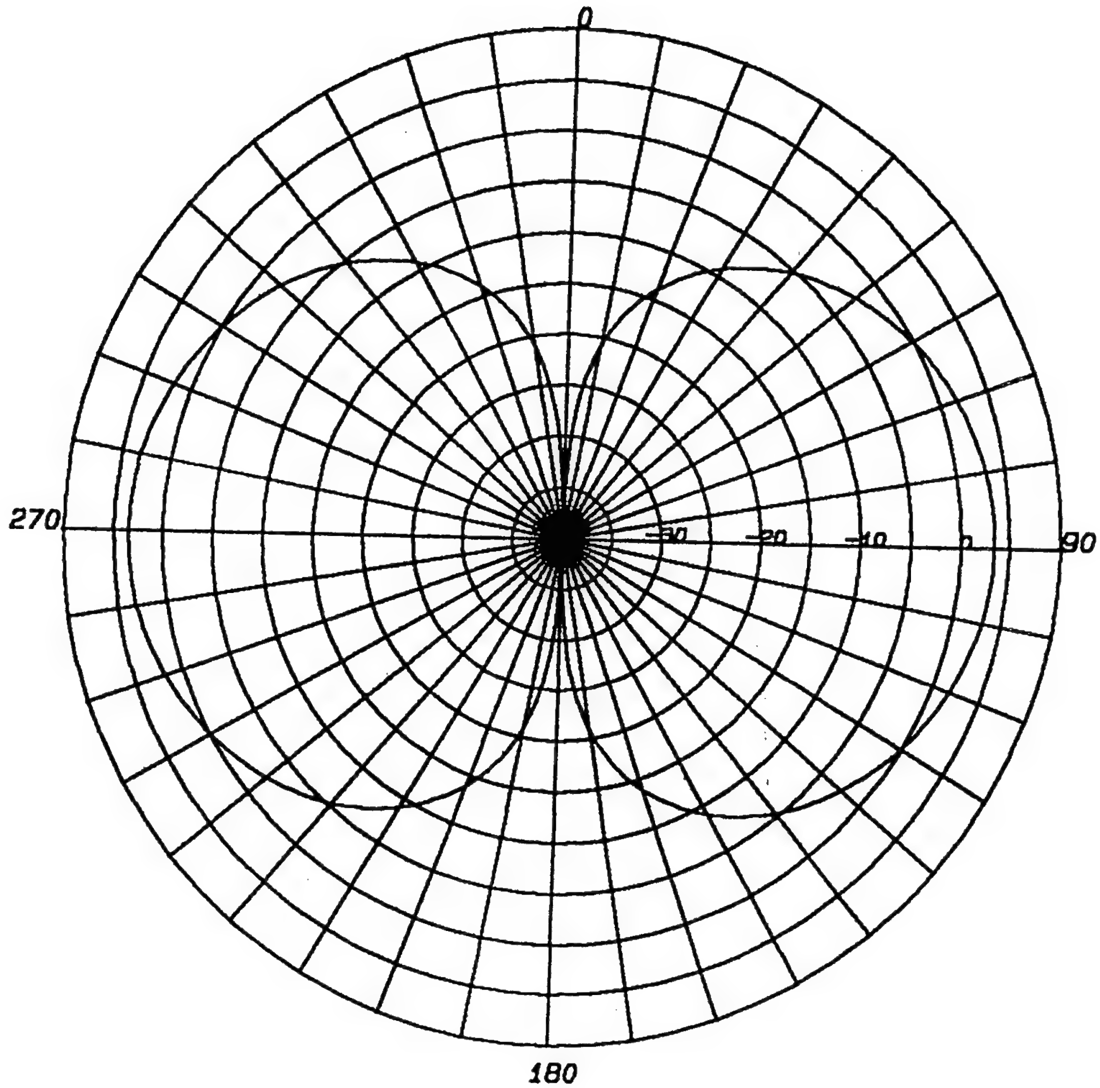

Four Dipole UHF Antenna : L = .4M
Frequency = 225 MHz : Scale is dBi
Gain = 3.46 dBi : Theta = 89 Degrees

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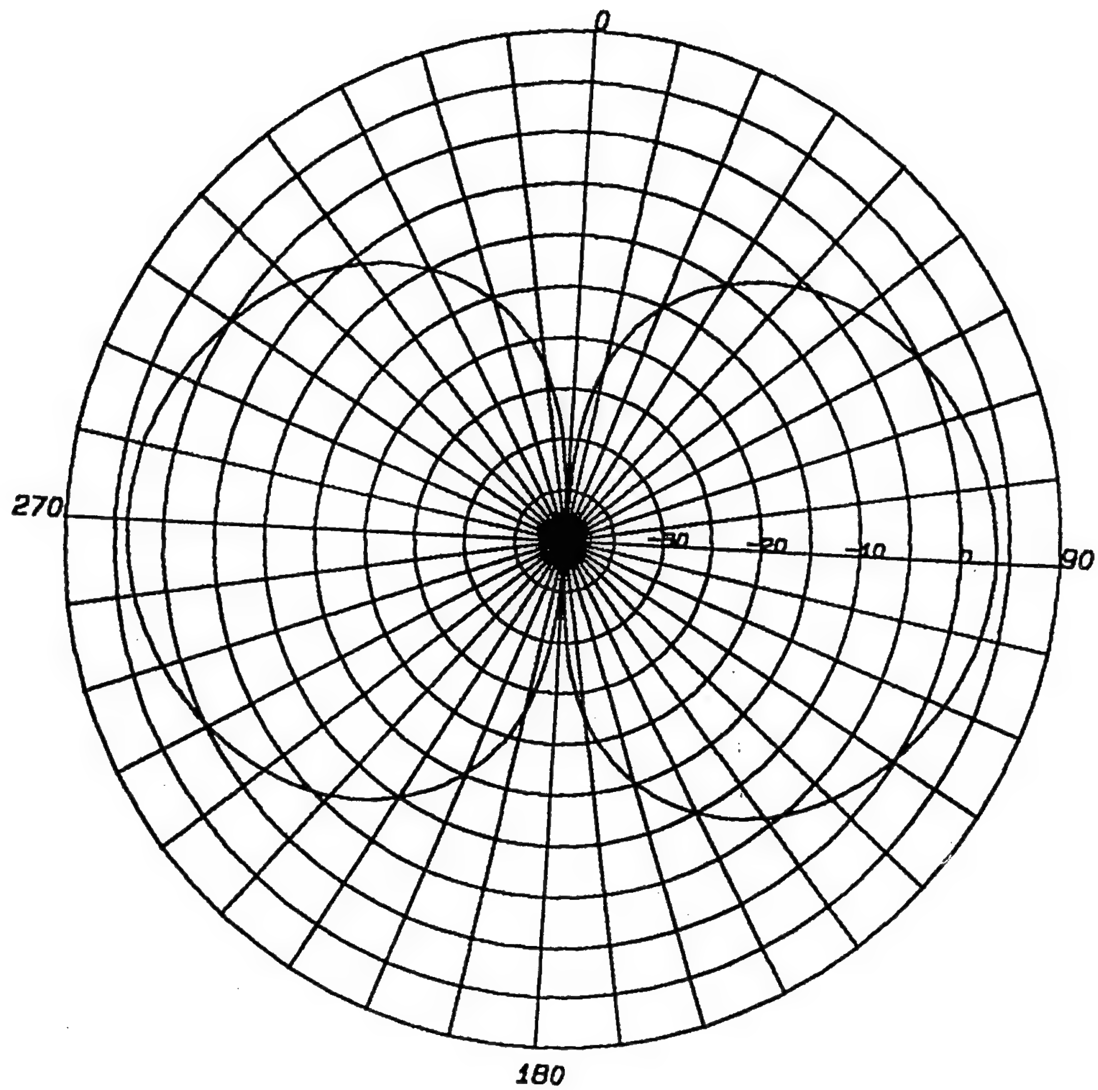
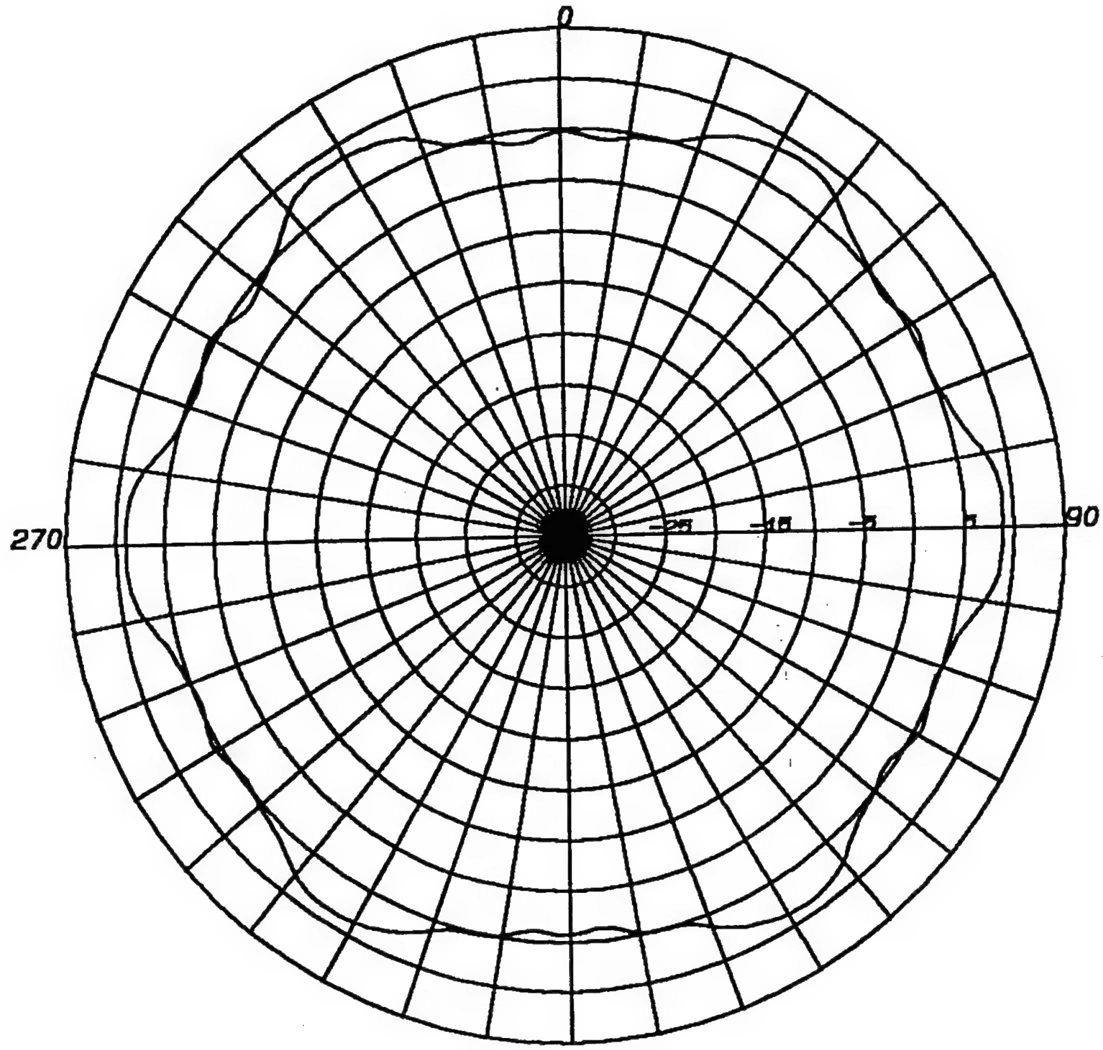
Mineral Wells, Texas



Four Dipole UHF Antenna : L = .4M
Frequency = 240 MHz : Scale is dBi
Gain = 3.64 dBi : Theta = 89 Degrees

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 90 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

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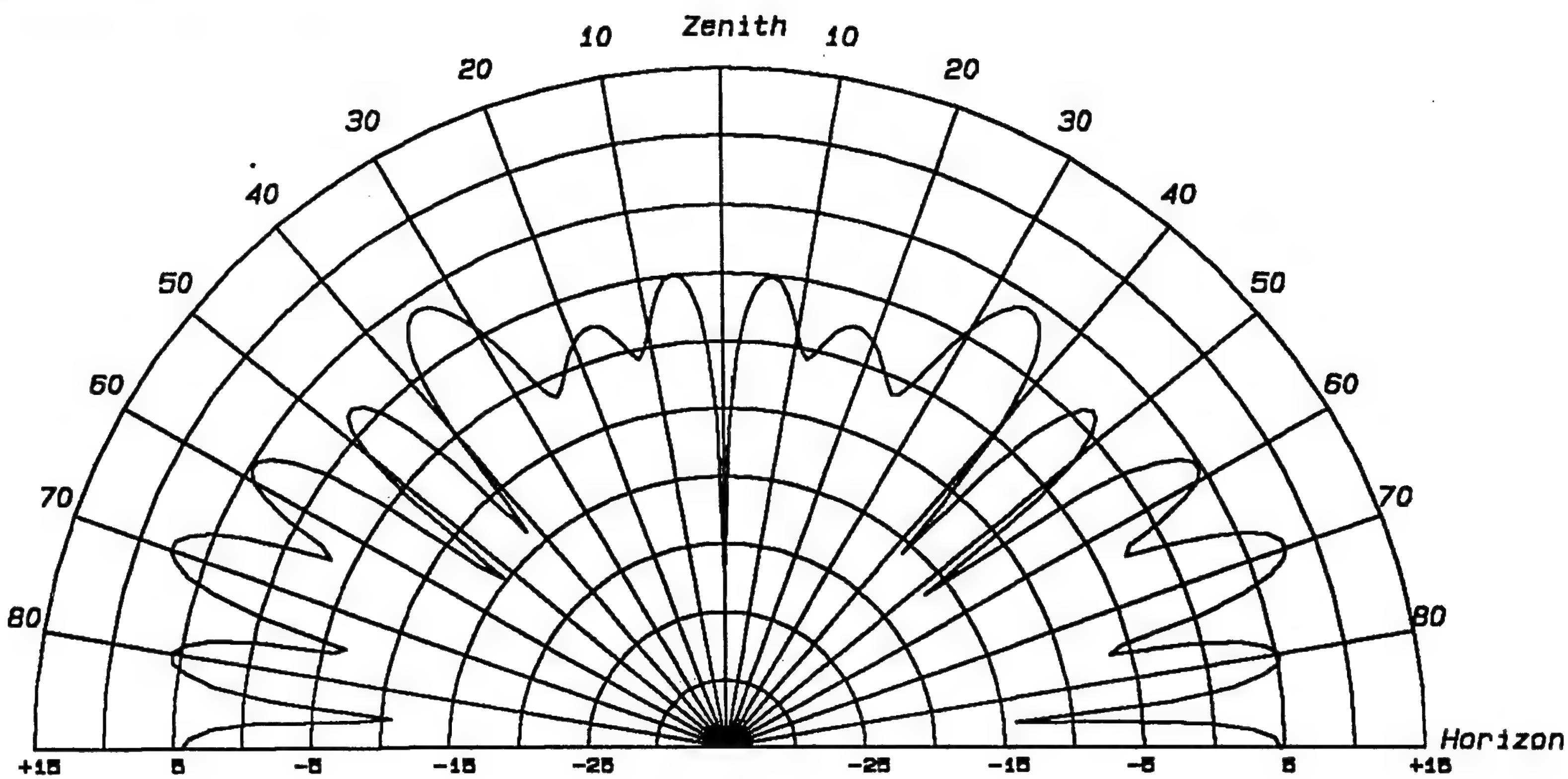
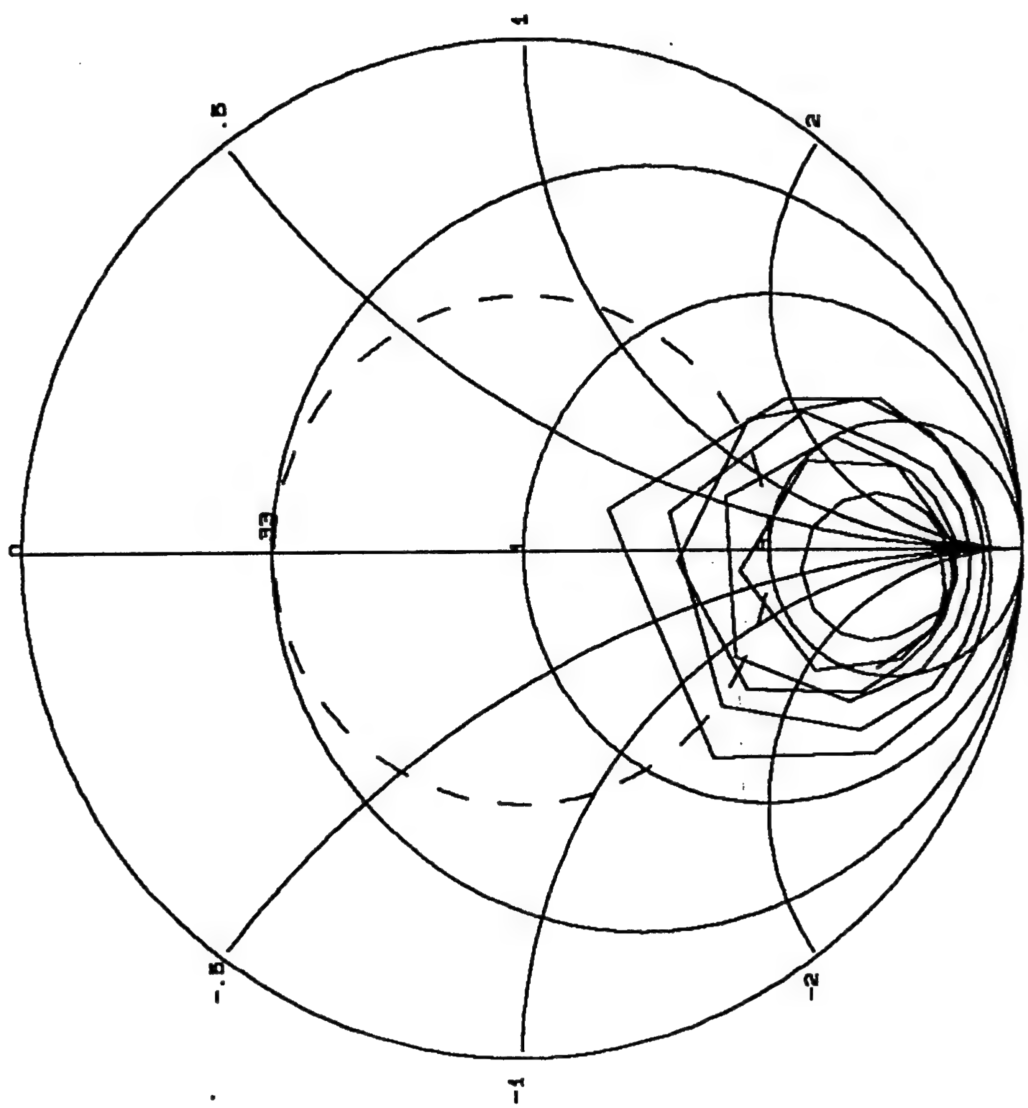
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 90 MHz : Dielectric Mast
Gain = 7.78 dBi : Theta = 70 Degrees
Perfect Ground : Leg = 10 Meters

APPENDIX C

Impedances and Radiation Patterns of Antenna With Vertical 1.5 Meter Rod Added to the Top of the Structure



Three Rhombic Antenna Array
Six Feed Array : No Mast : L = 10 M
Impedance = 50 Ohms : 04-04-1998

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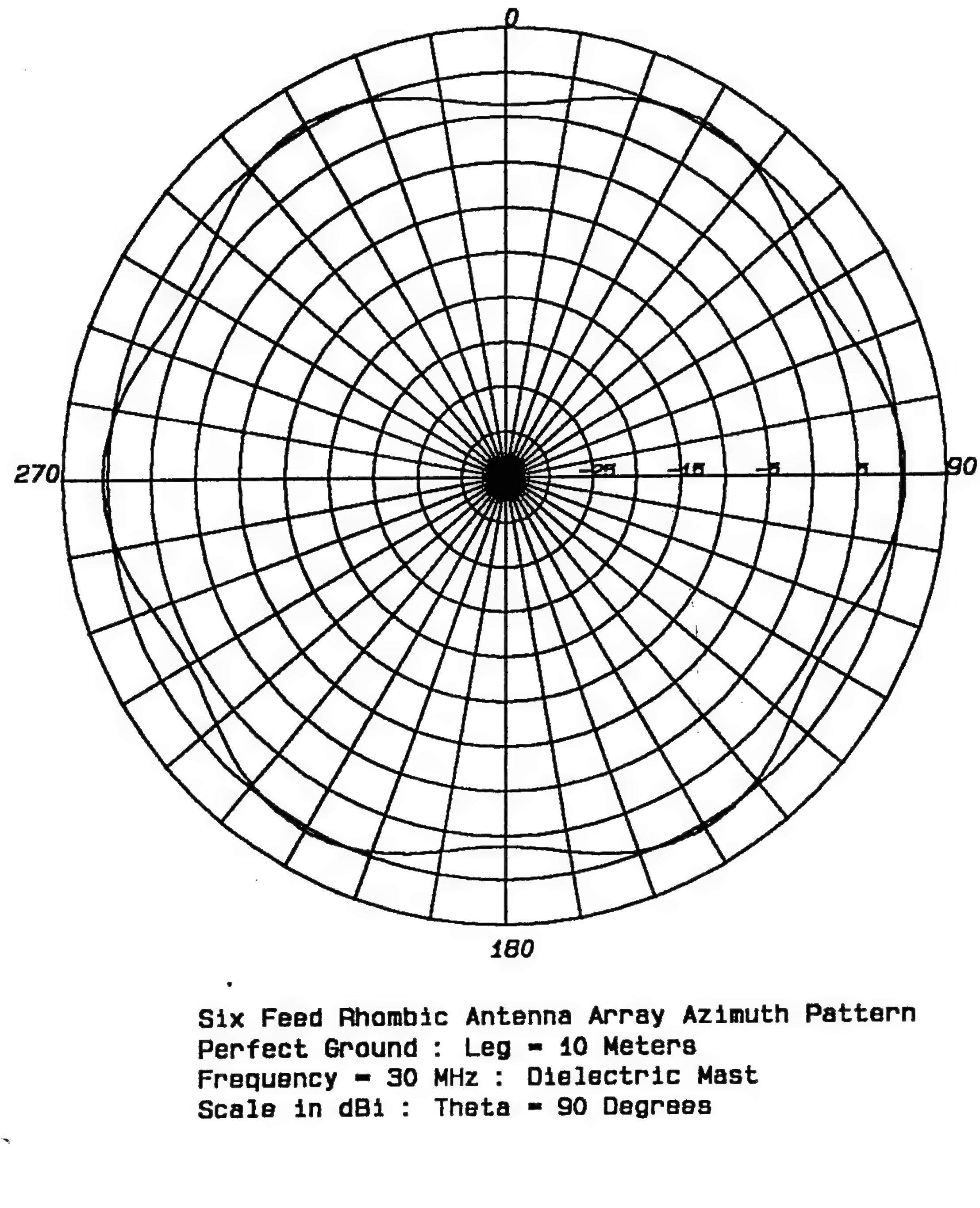

Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 30 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

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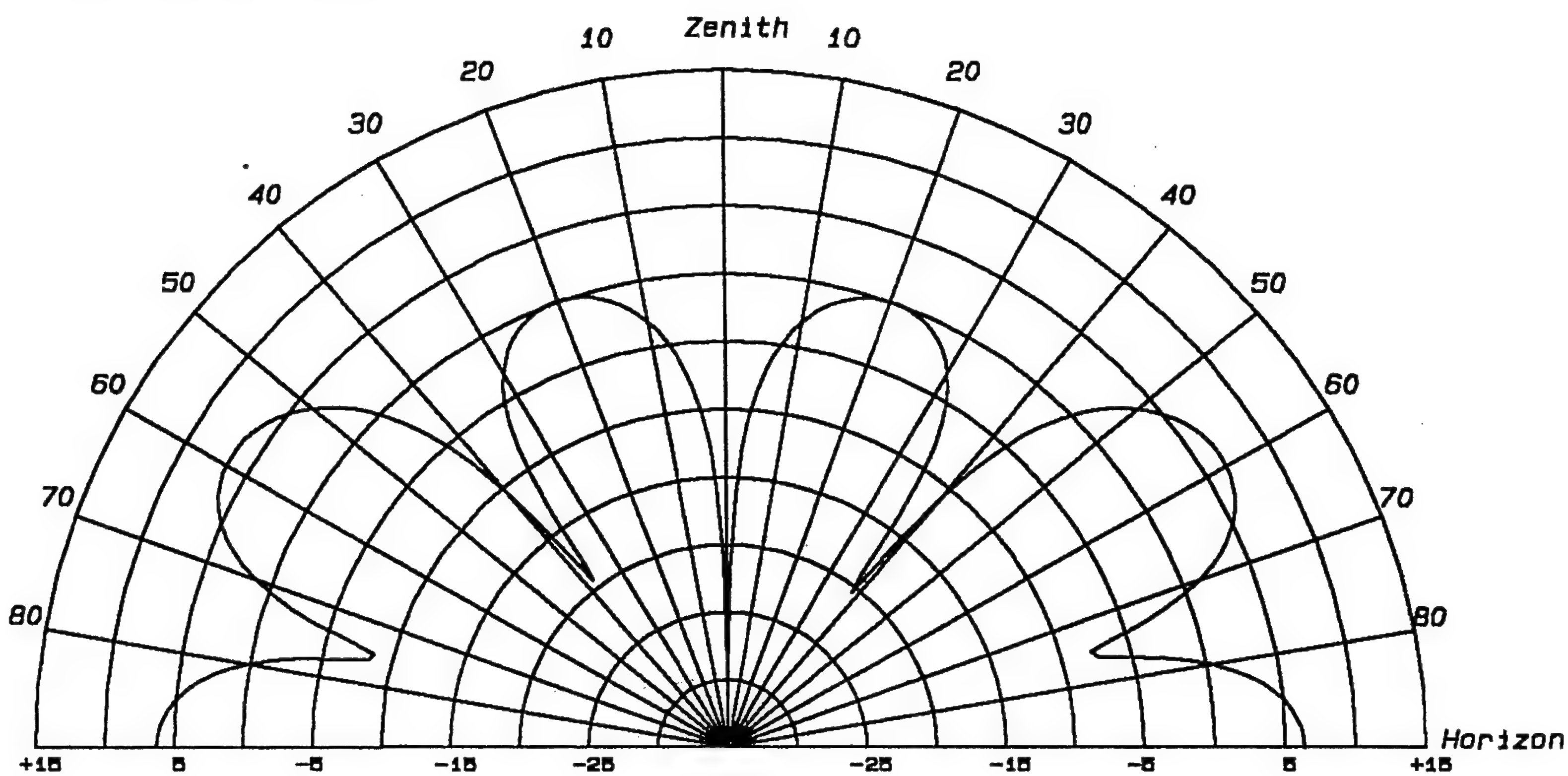

Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 30 MHz : Dielectric Mast
Gain = 6.64 dBi : Theta = 59 Degrees
Perfect Ground : Leg = 10 Meters

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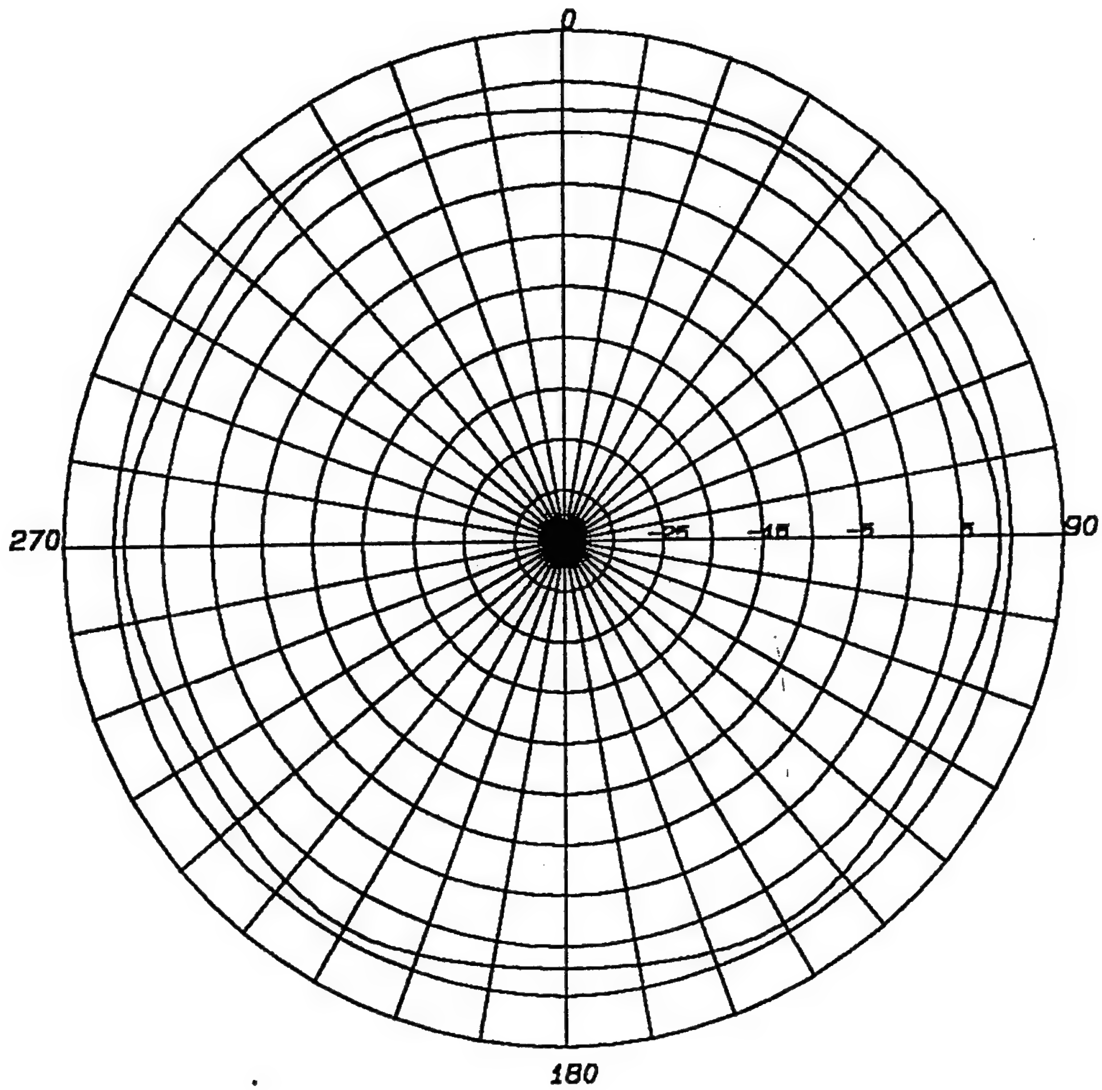
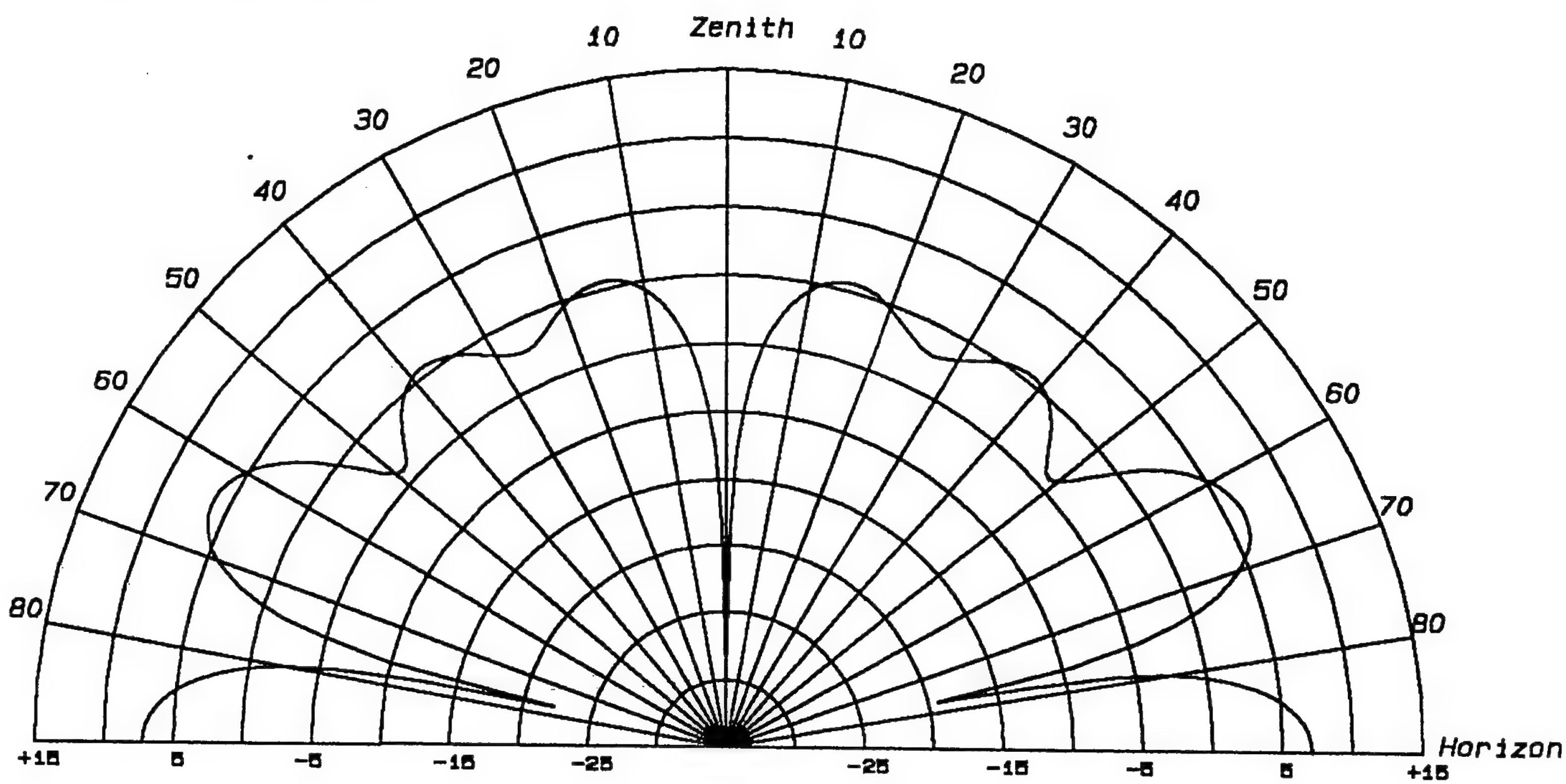


Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 35 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 35 MHz : Dielectric Mast
Gain = 7.26 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

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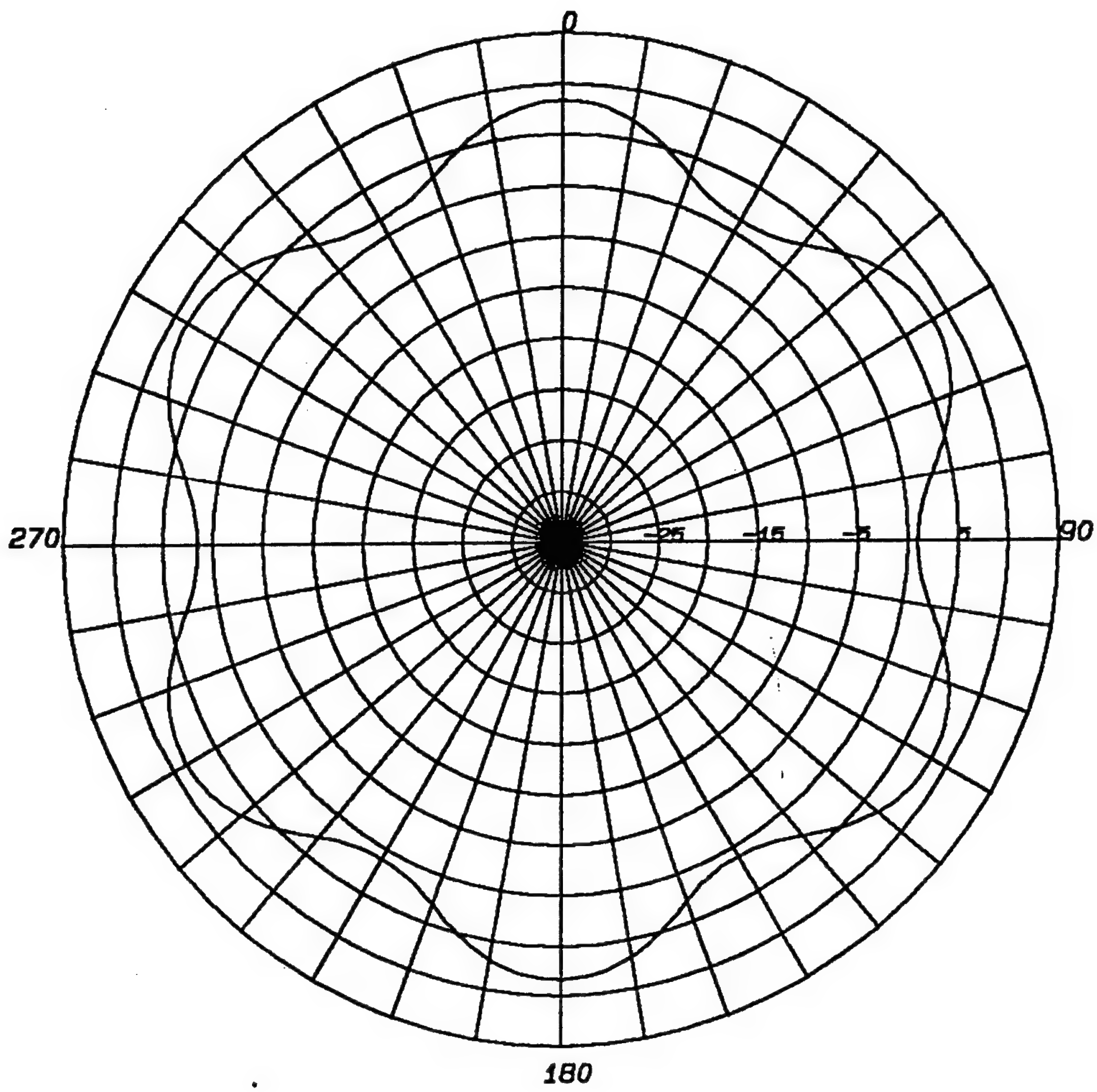

Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 40 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

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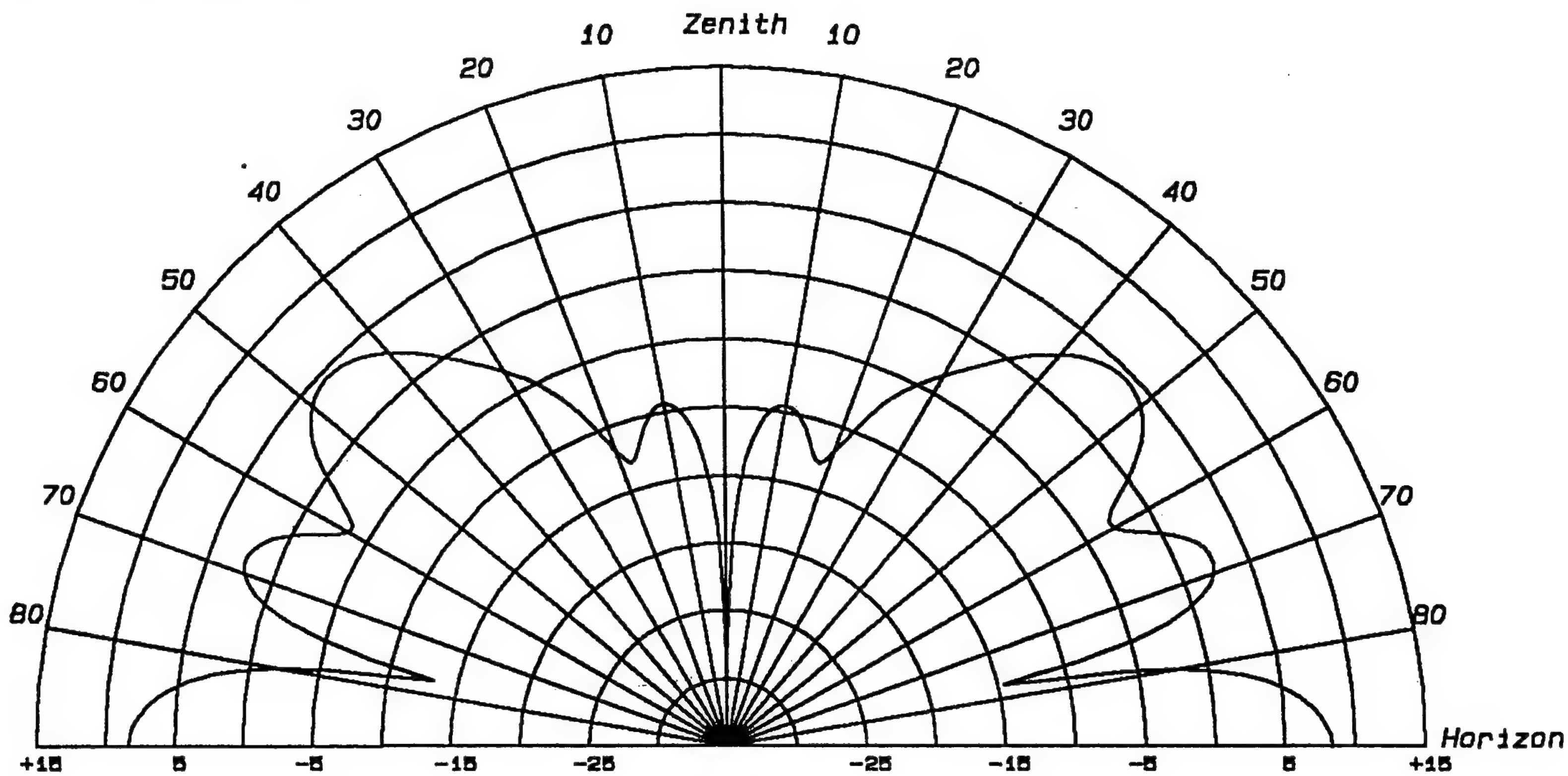
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 40 MHz : Dielectric Mast
Gain = 8.35 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

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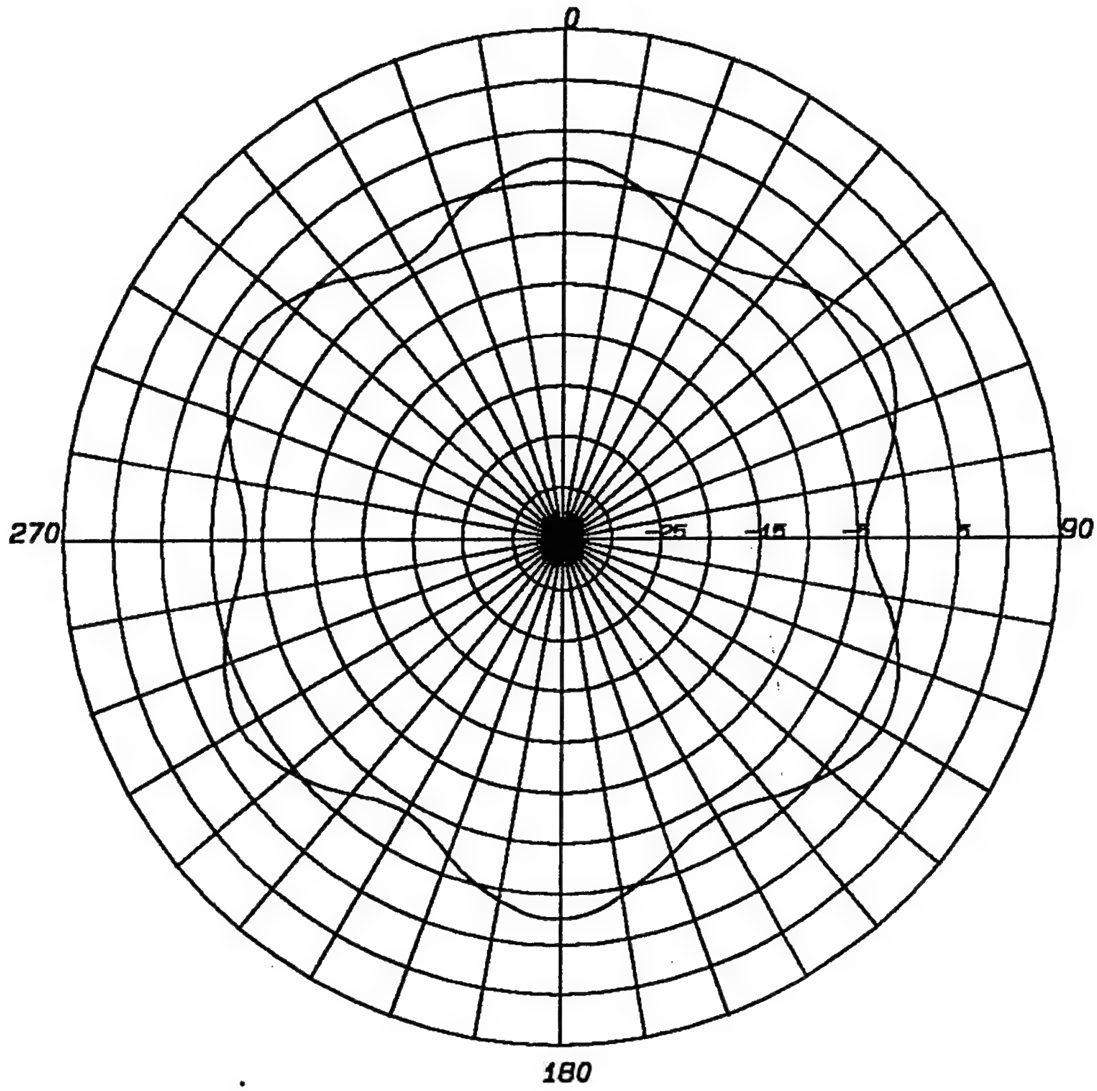

Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 45 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

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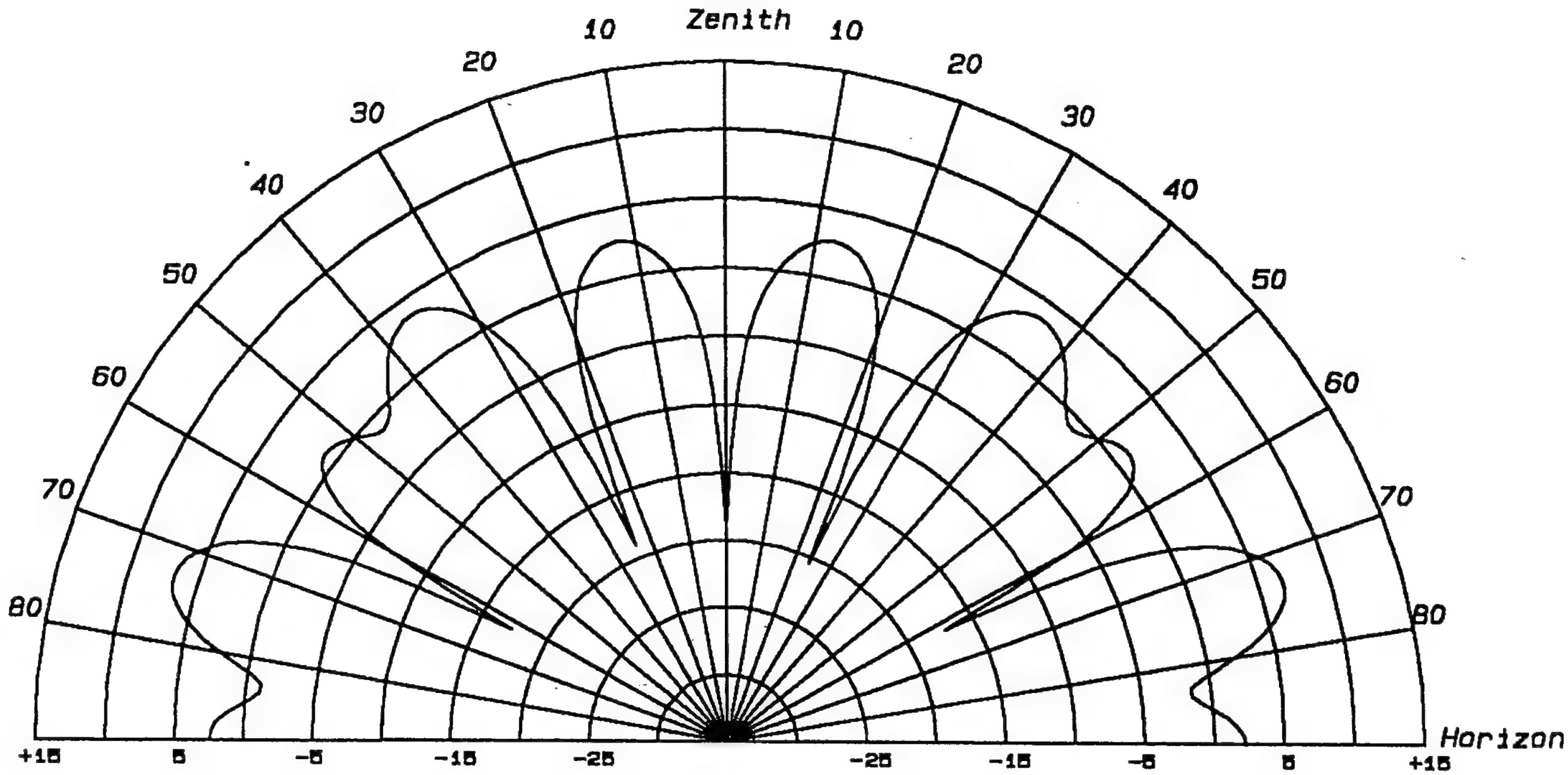
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 45 MHz : Dielectric Mast
Gain = 6.73 dBi : Theta = 73 Degrees
Perfect Ground : Leg = 10 Meters

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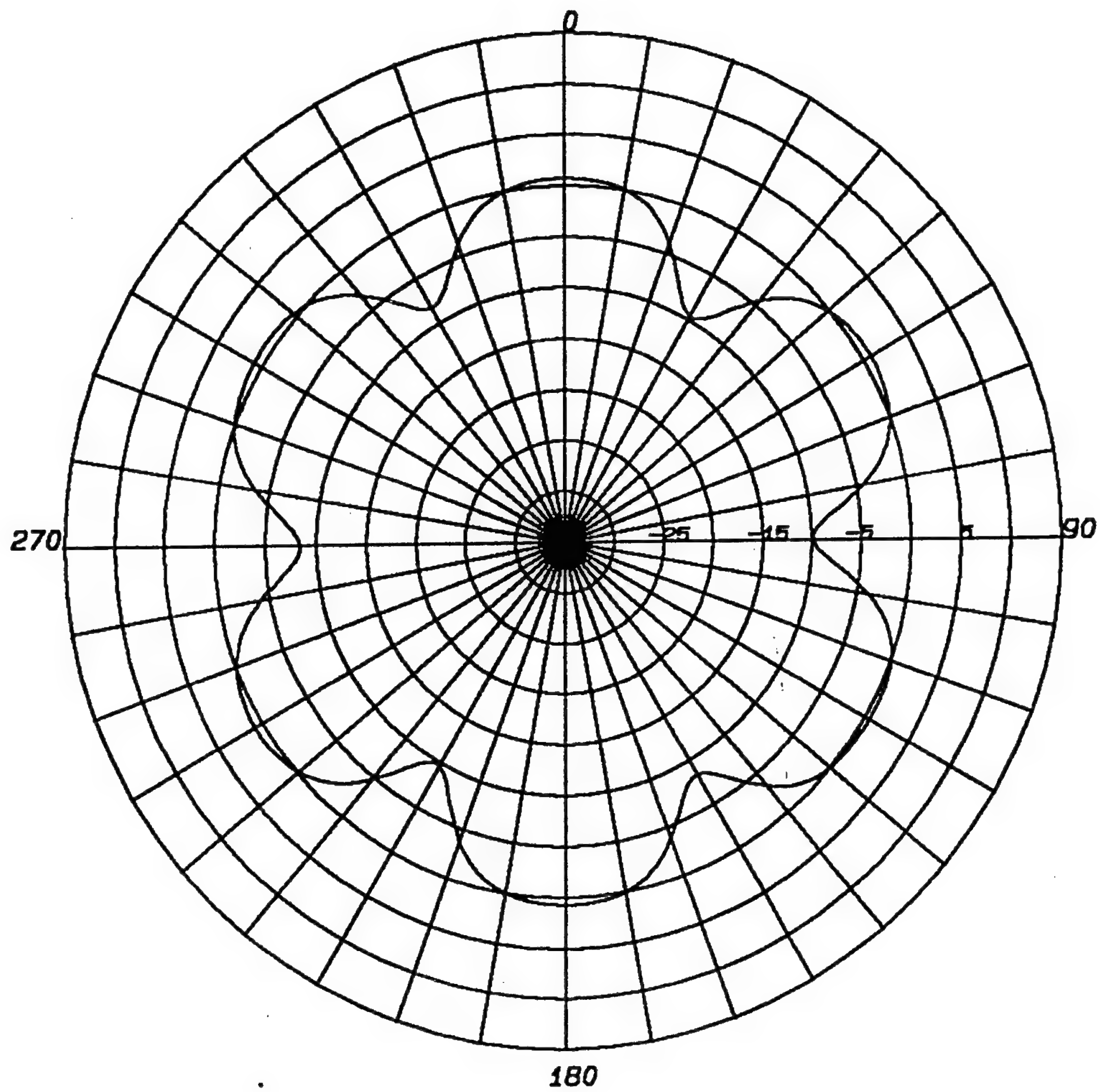

Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 50 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

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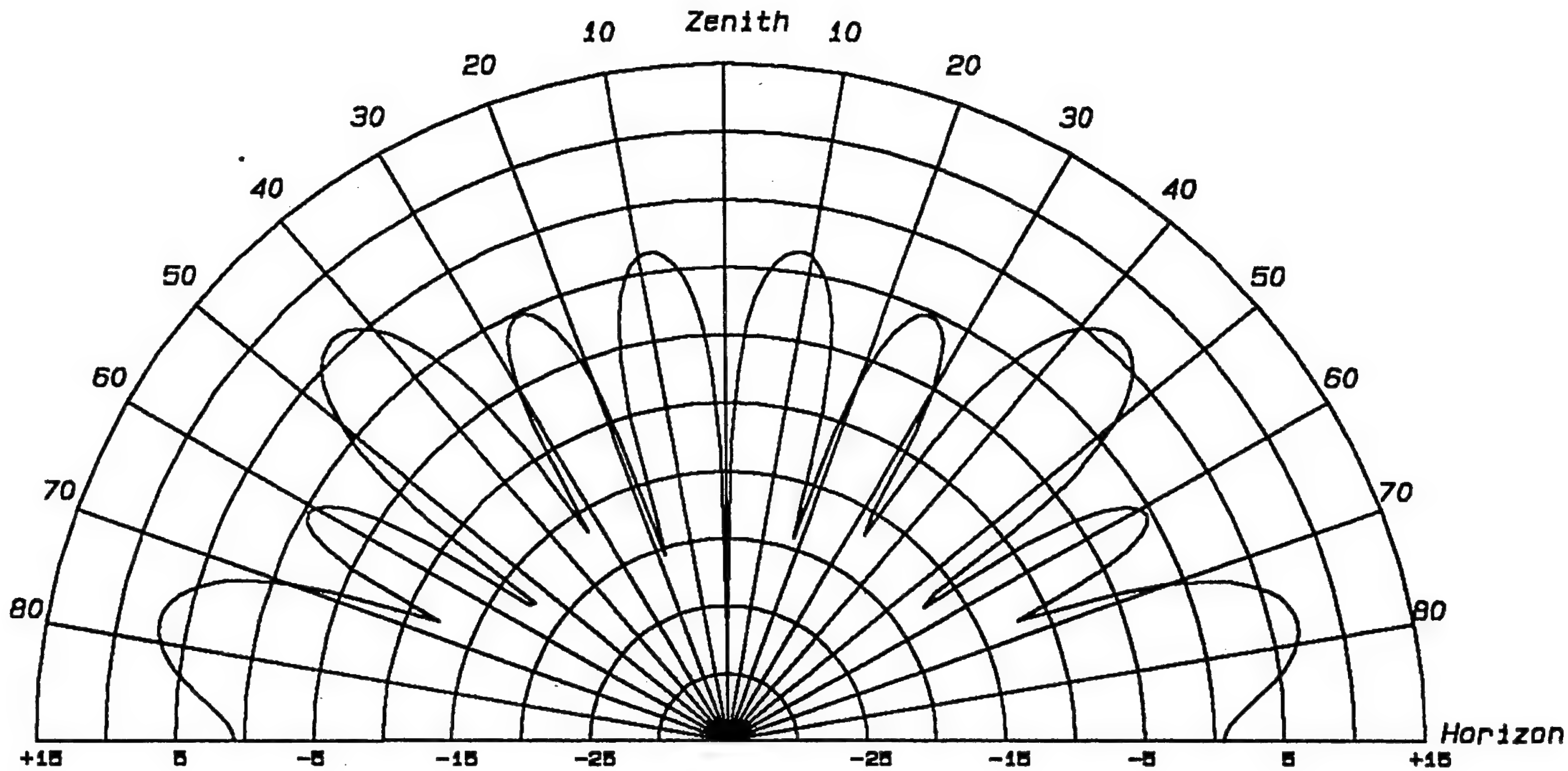

Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 50 MHz : Dielectric Mast
Gain = 6.96 dBi : Theta = 78 Degrees
Perfect Ground : Leg = 10 Meters

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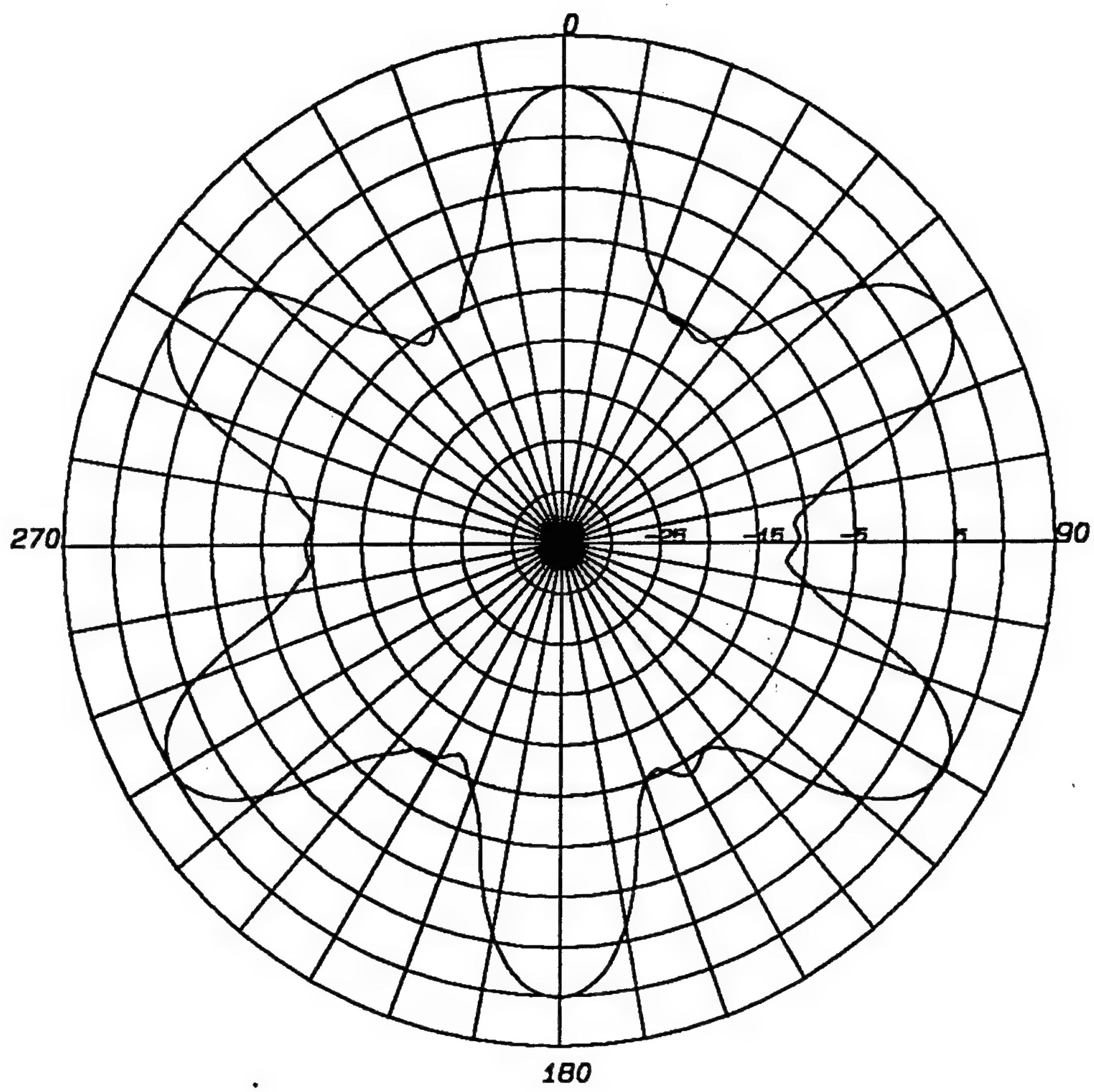

Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 55 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

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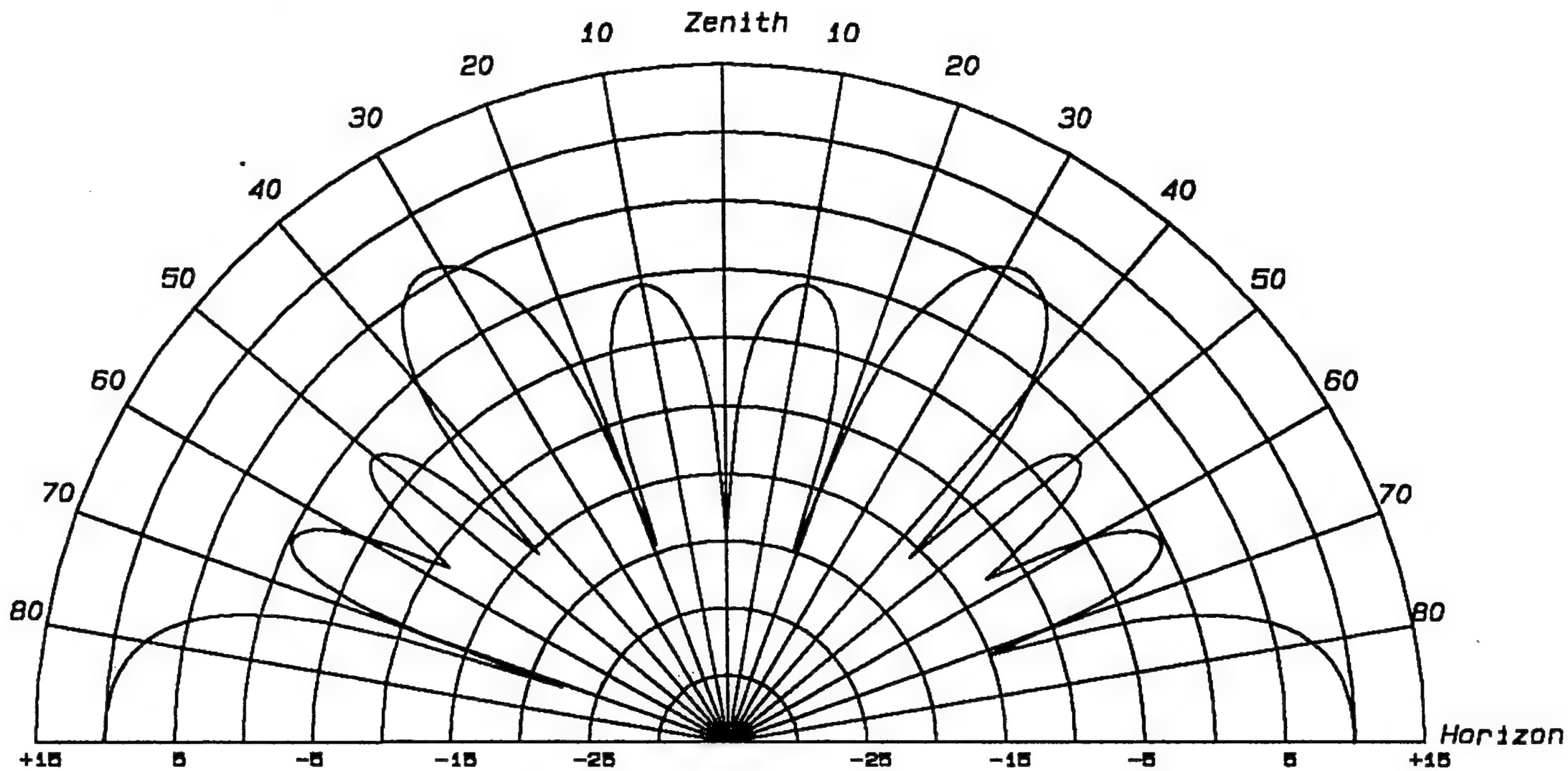
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 55 MHz : Dielectric Mast
Gain = 10.1 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

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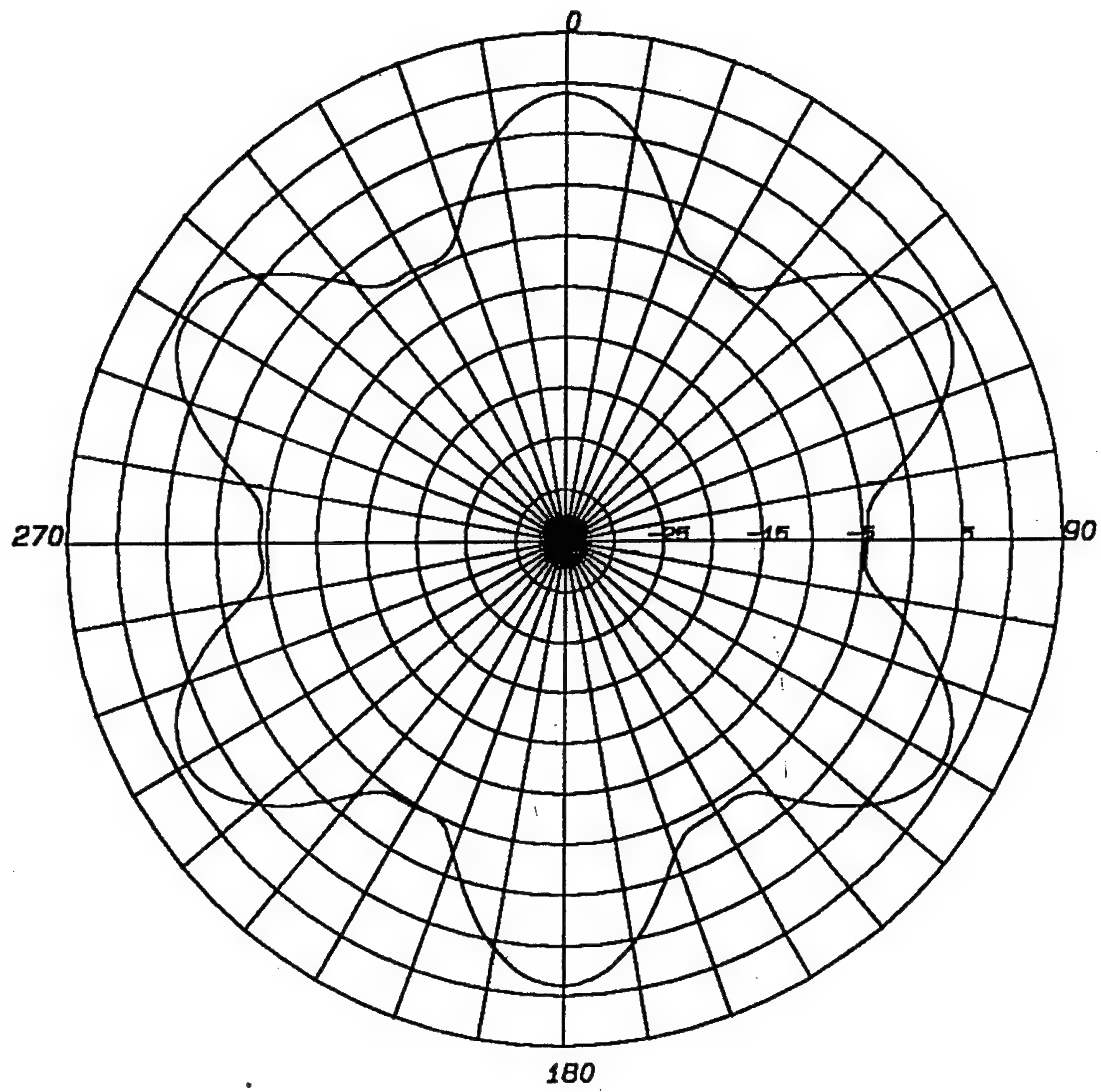
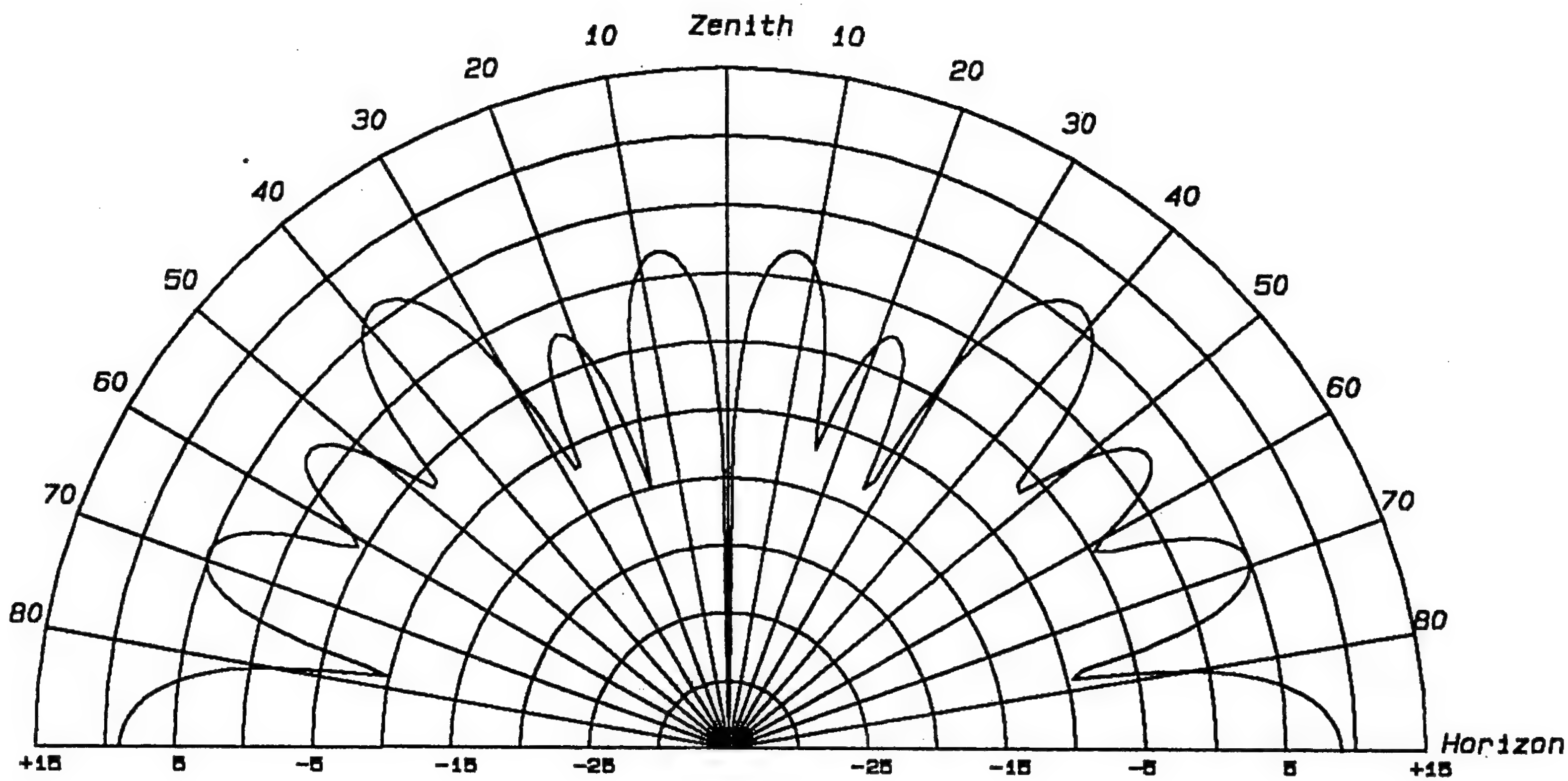
Mineral Wells, Texas



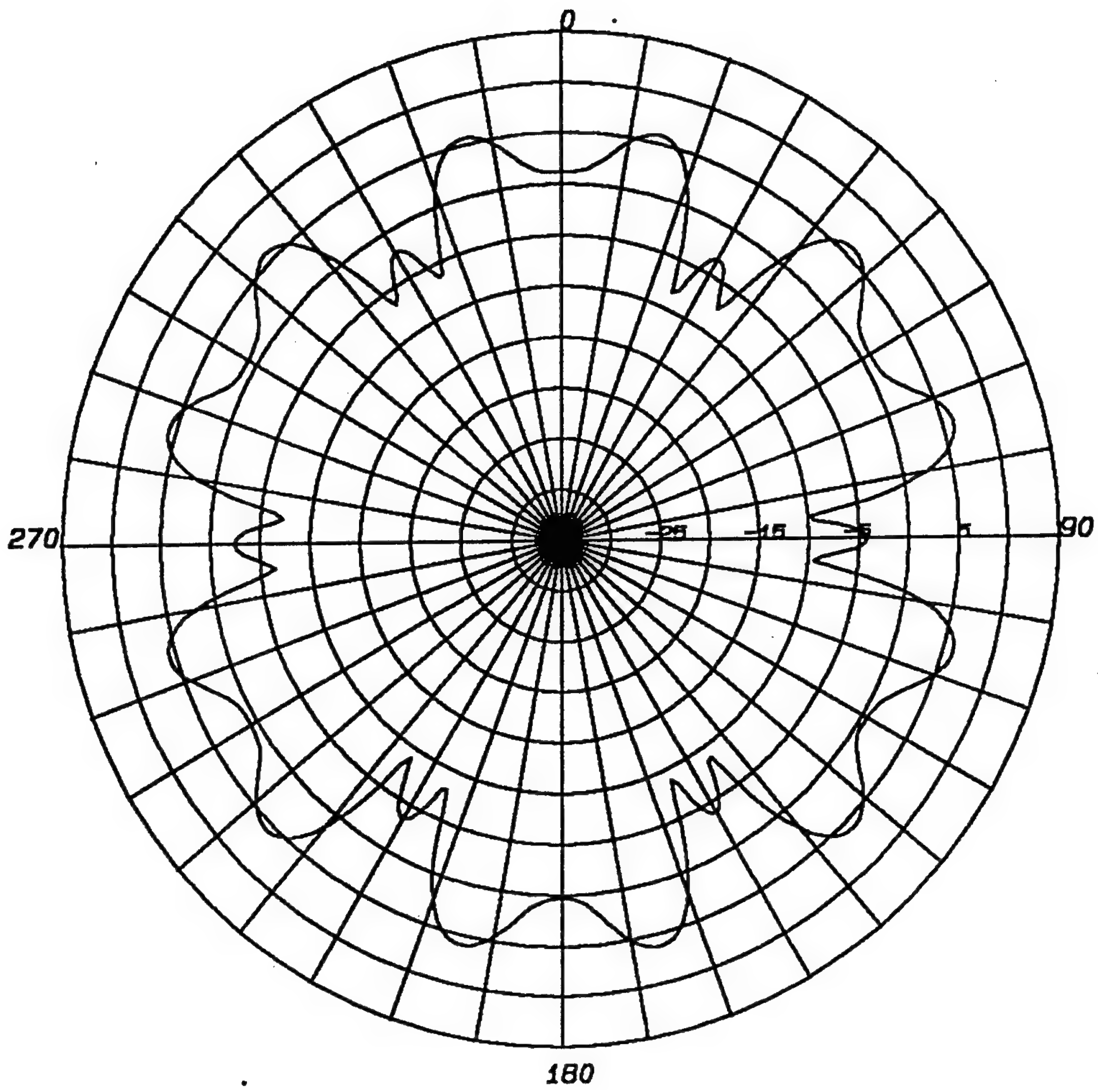
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 60 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



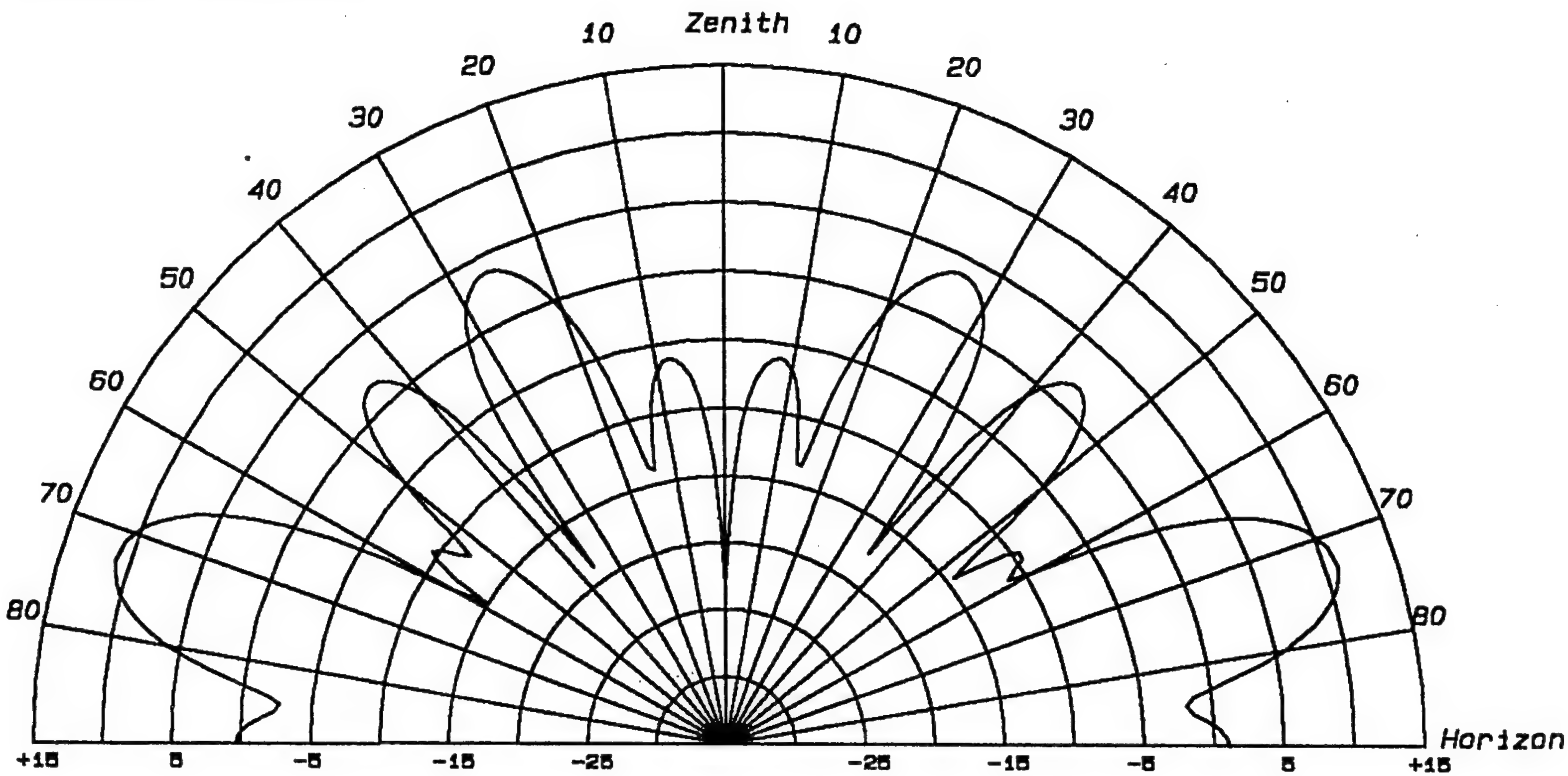
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 60 MHz : Dielectric Mast
Gain = 9 dBi : Theta = 90 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



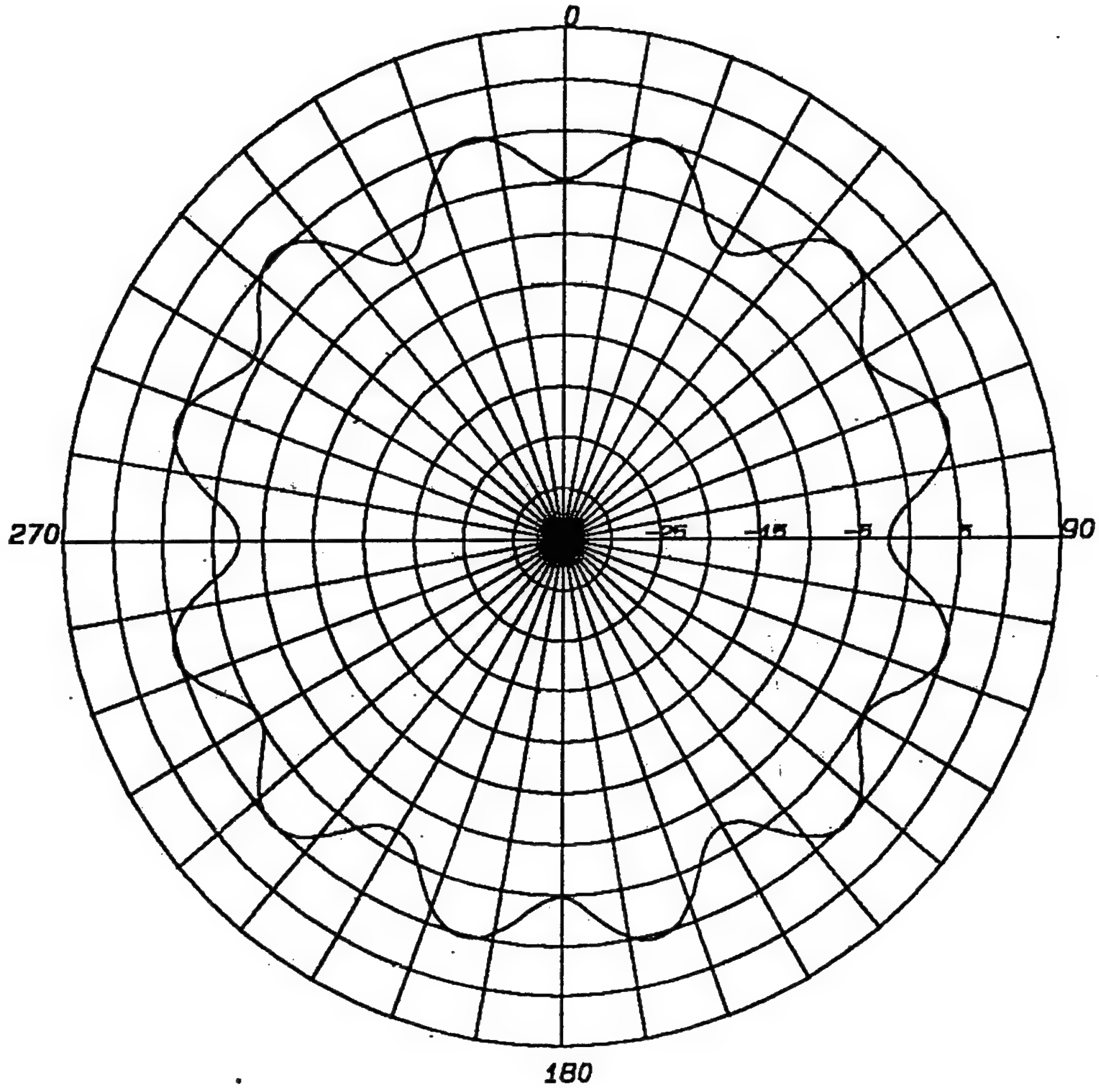
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 65 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



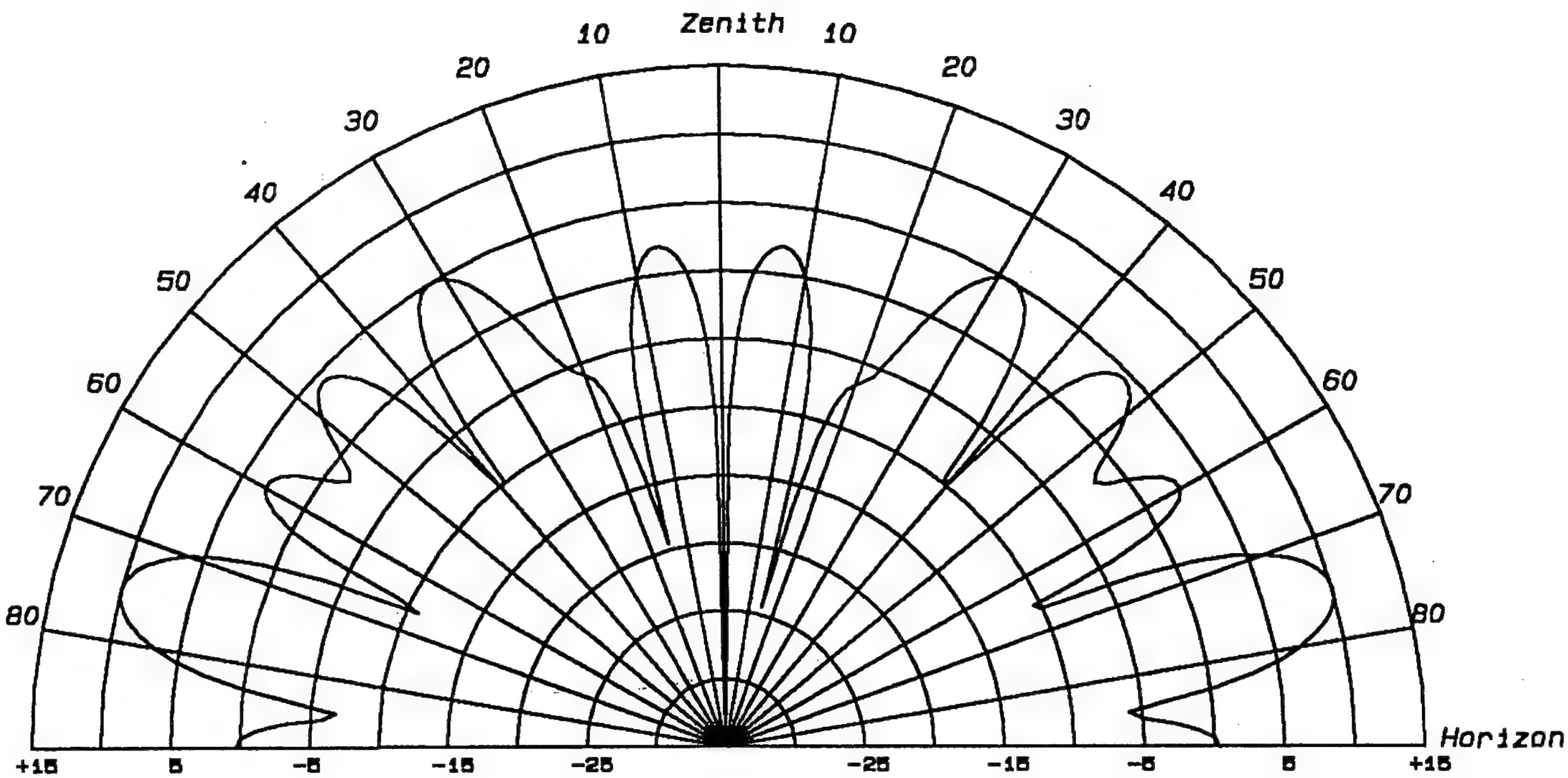
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 65 MHz : Dielectric Mast
Gain = 11 dBi : Theta = 73 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



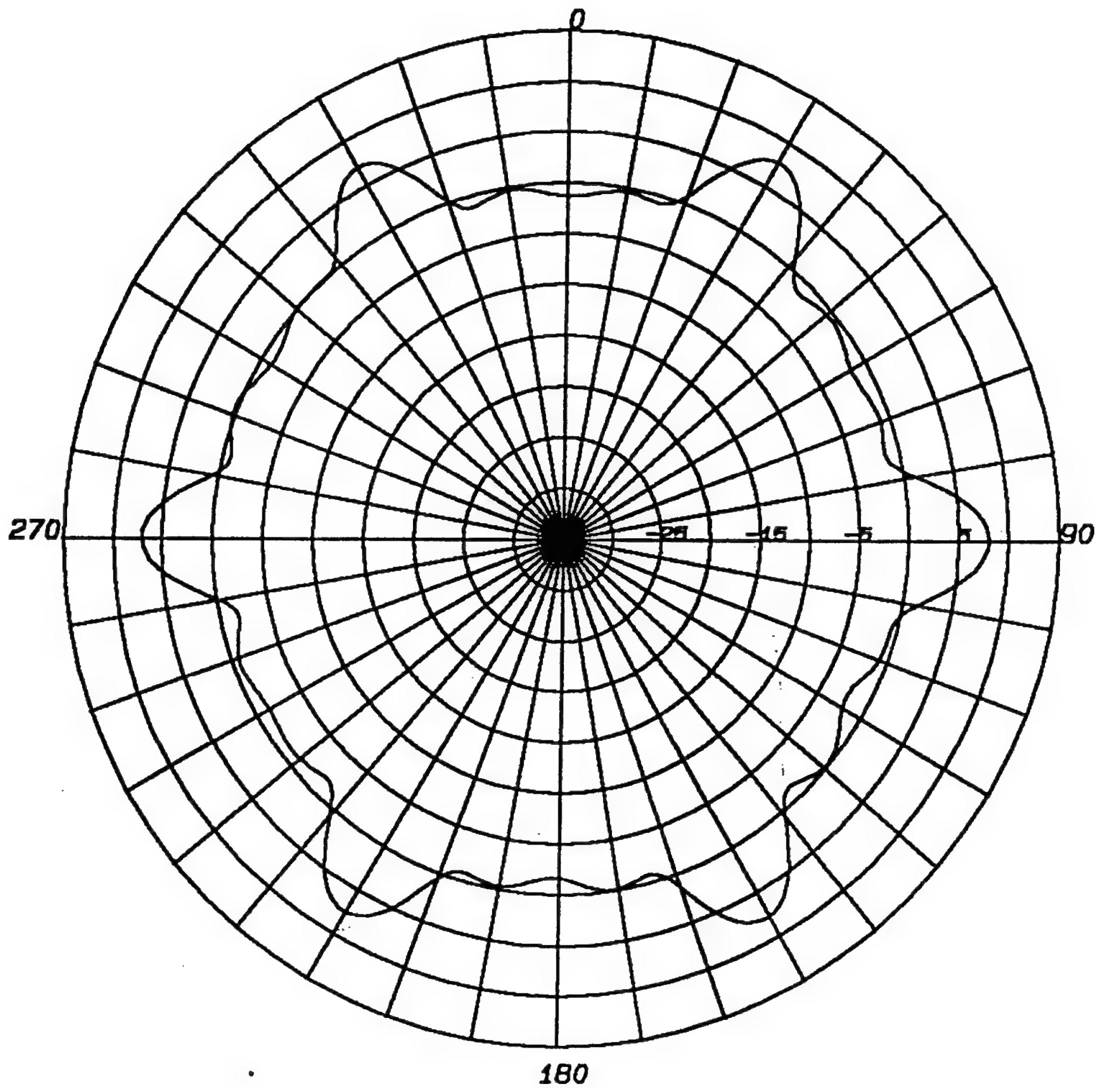
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 70 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



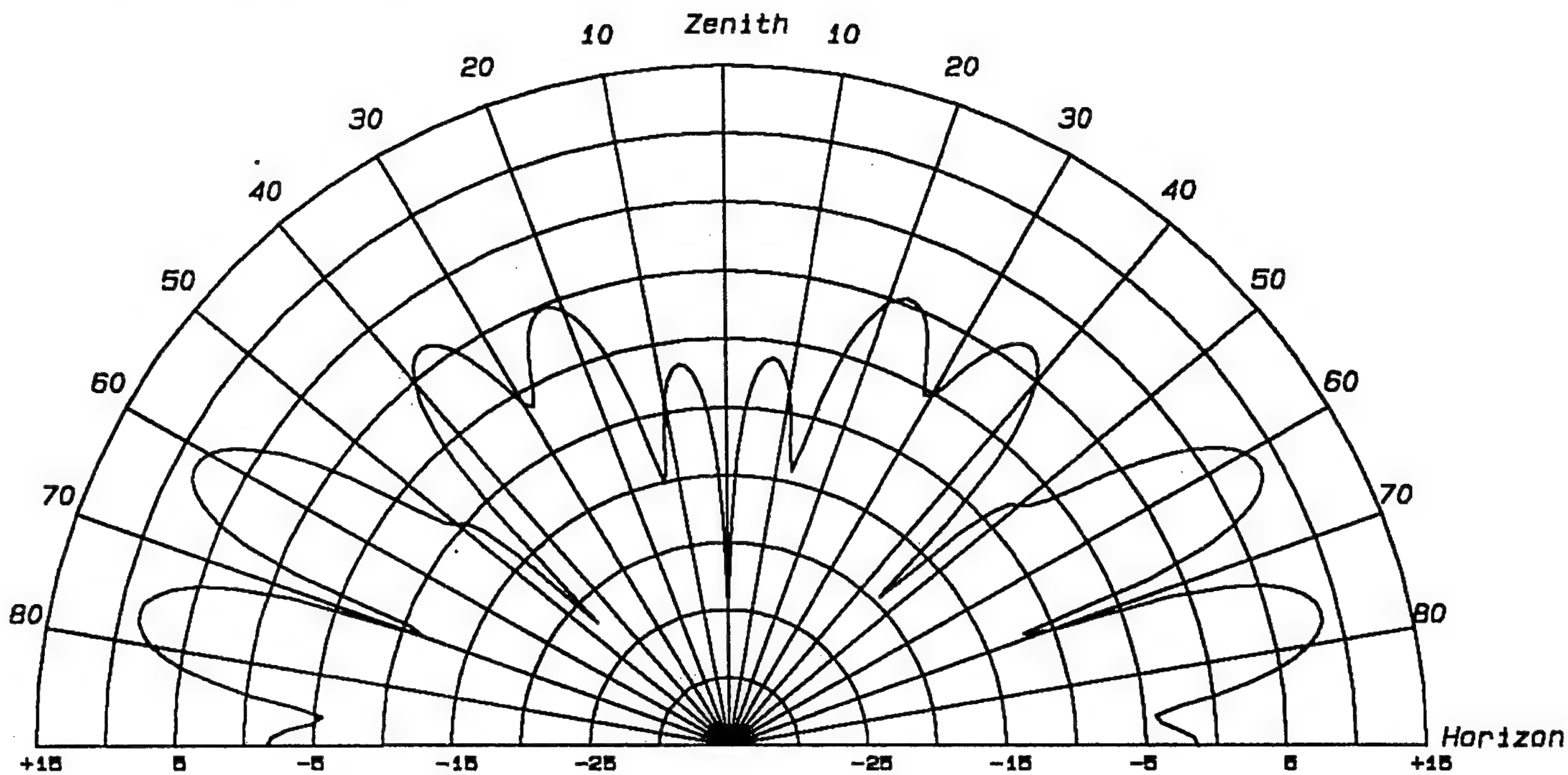
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 70 MHz : Dielectric Mast
Gain = 10.1 dBi : Theta = 75 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



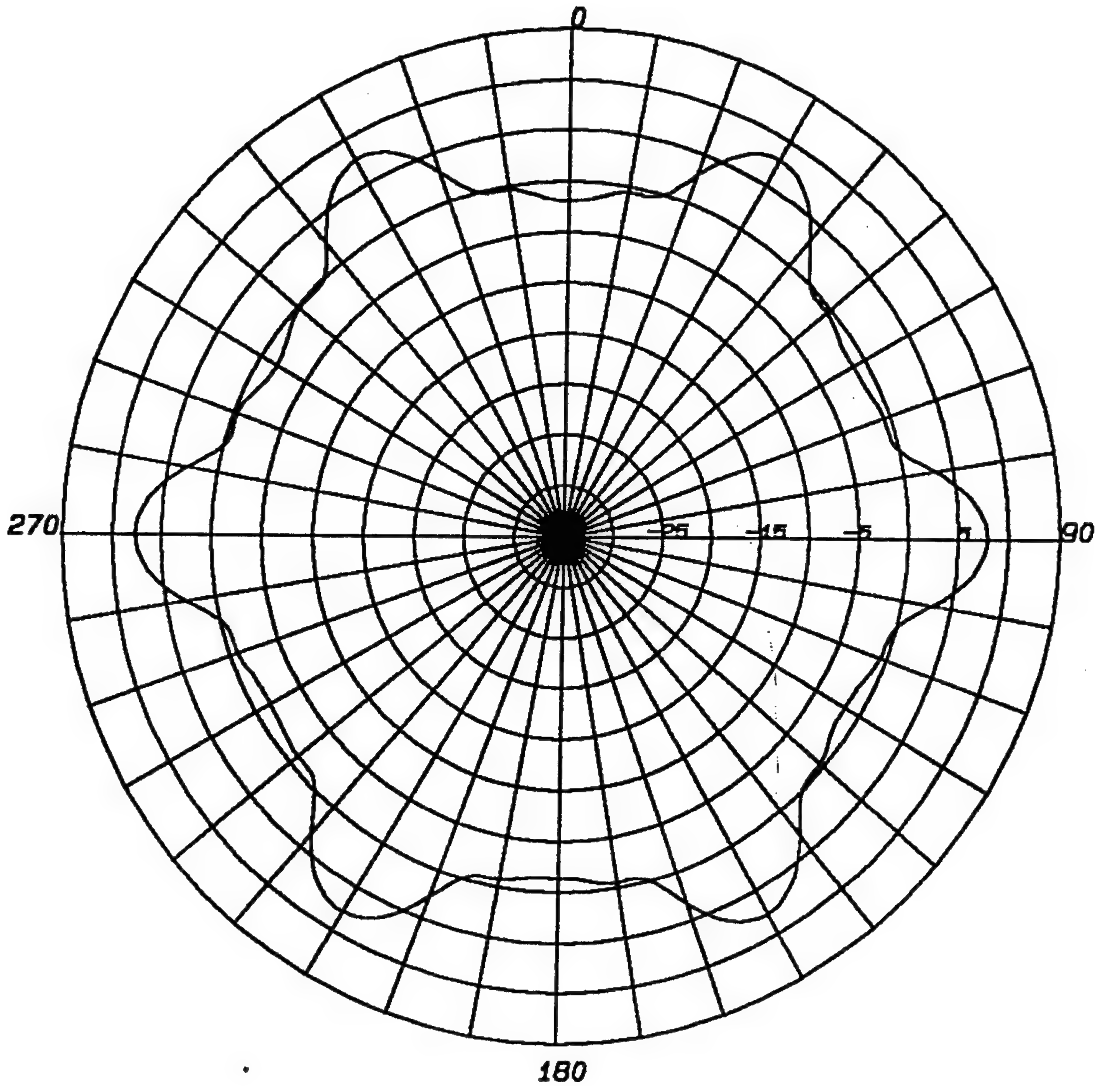
Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 75 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 75 MHz : Dielectric Mast
Gain = 8.76 dBi : Theta = 77 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 80 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

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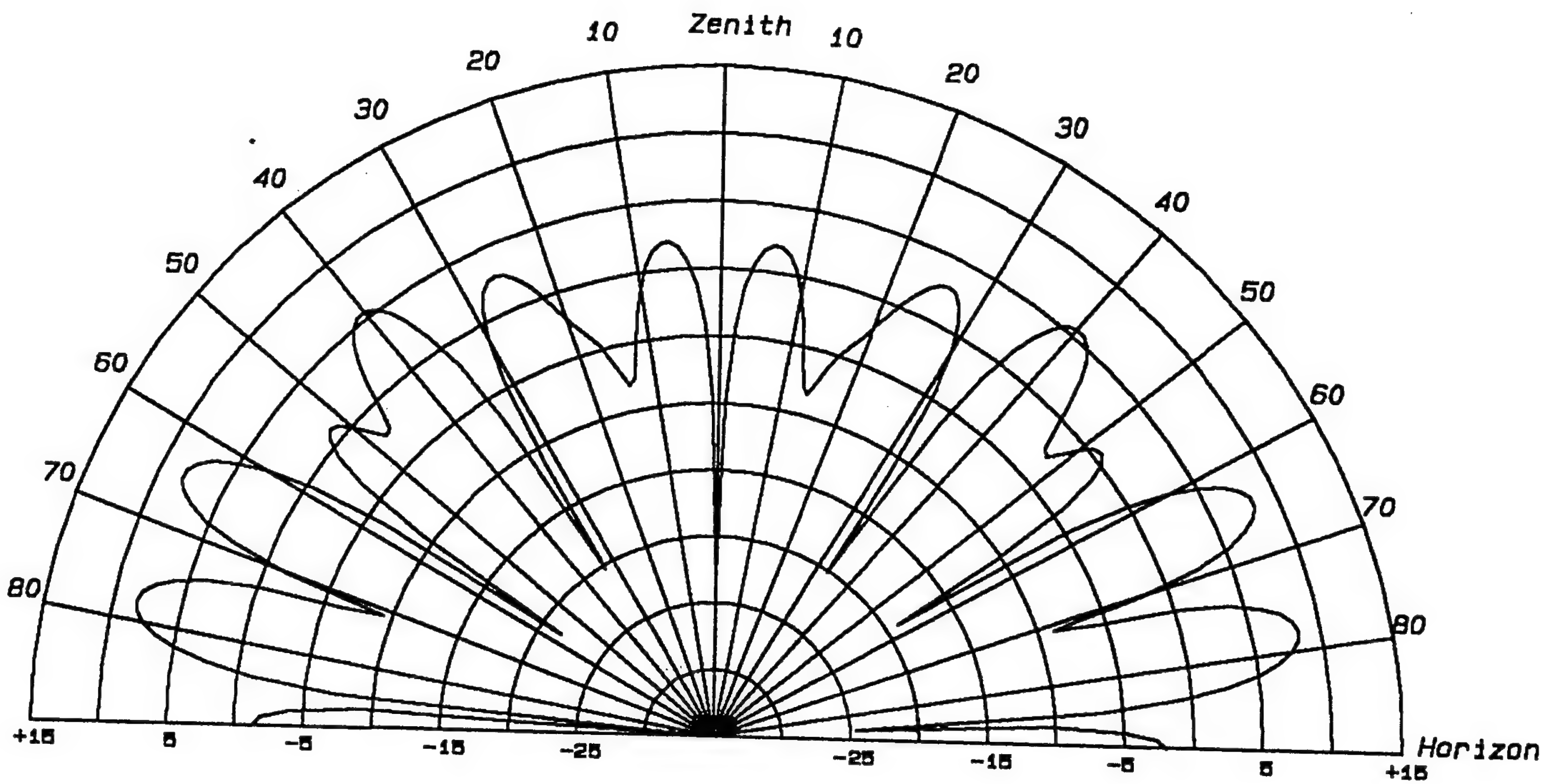
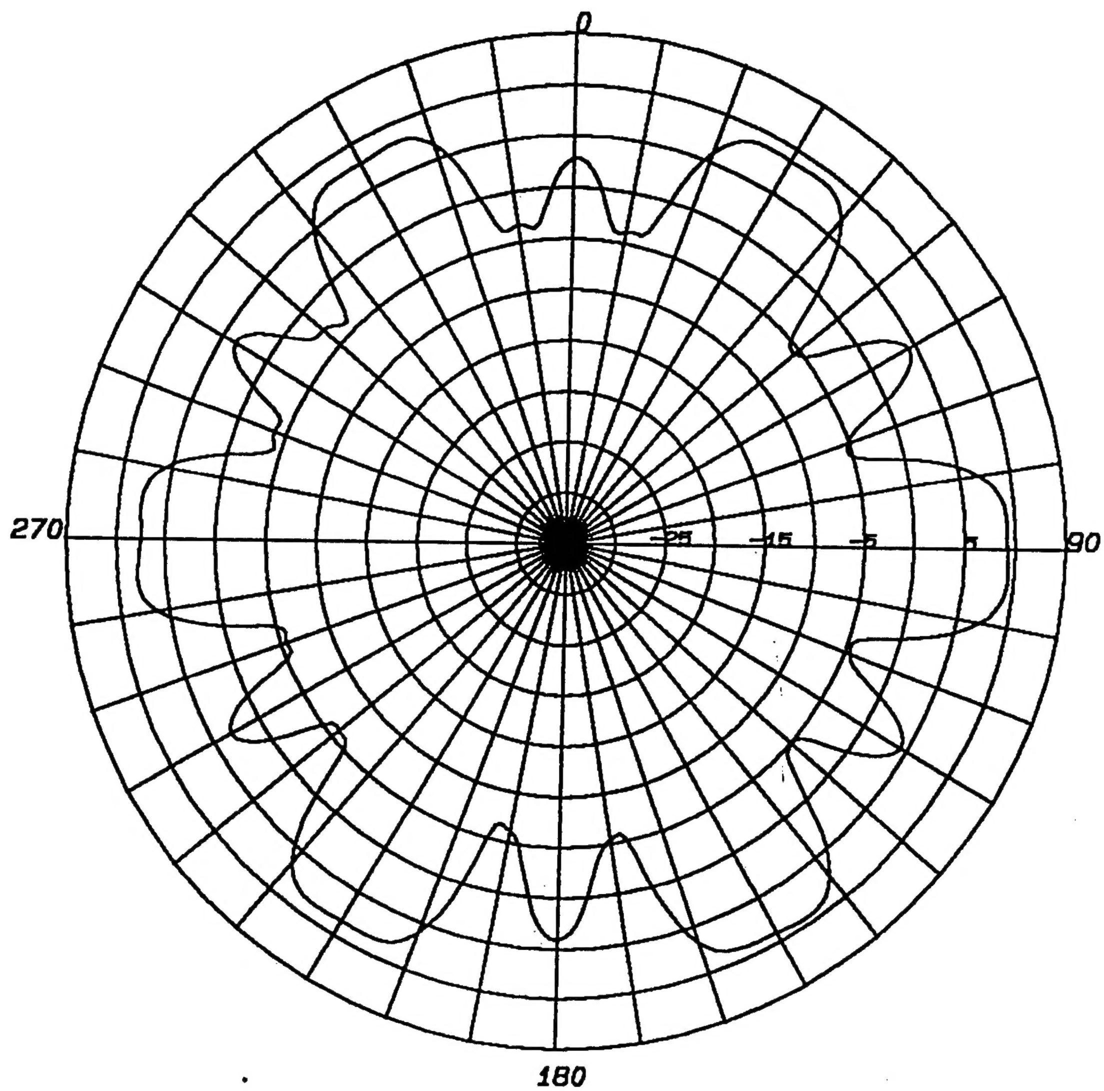
Mineral Wells, Texas



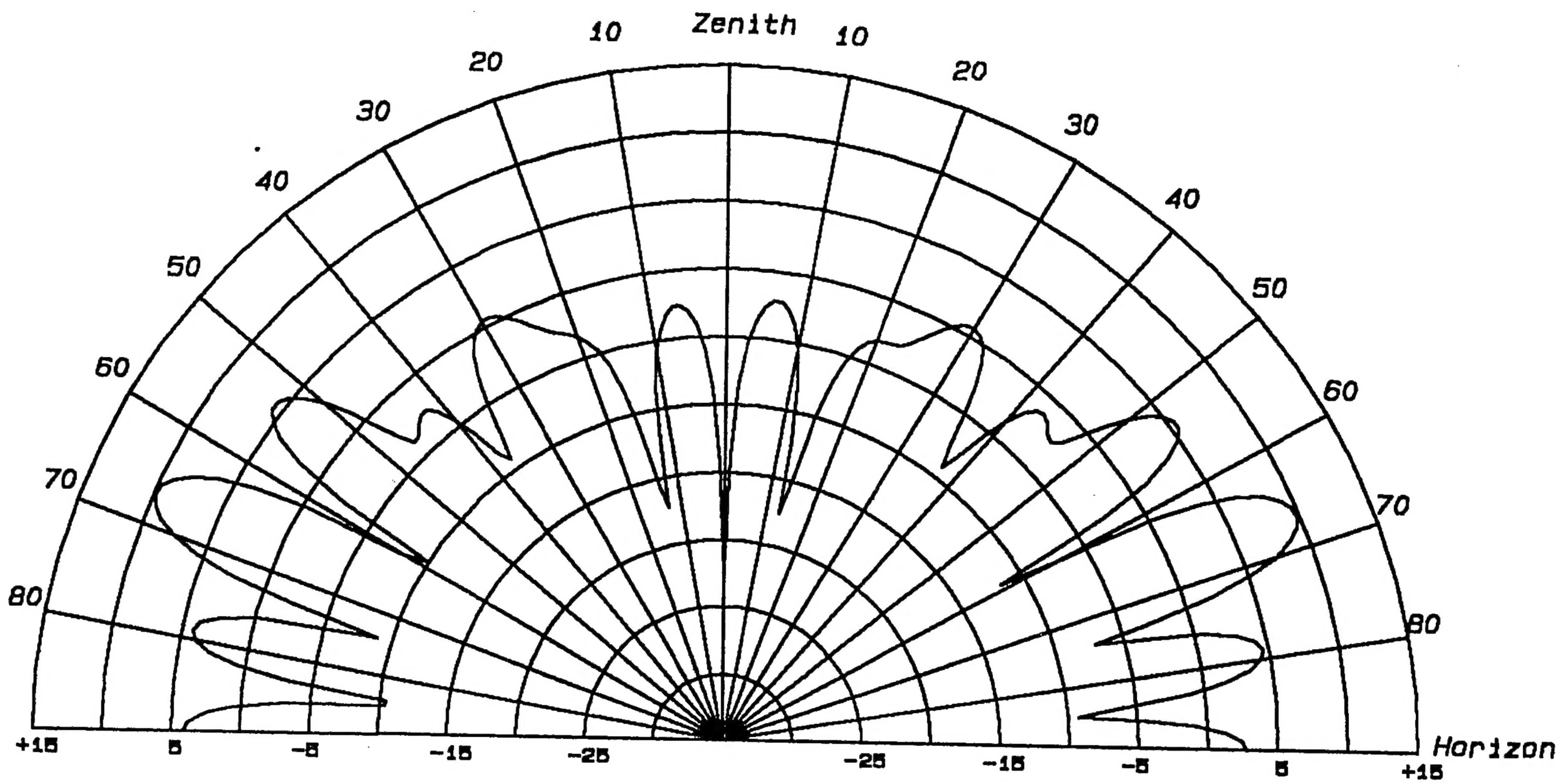
Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 80 MHz : Dielectric Mast
Gain = 8.39 dBi : Theta = 78 Degrees
Perfect Ground : Leg = 10 Meters

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 85 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 85 MHz : Dielectric Mast
Gain = 9.85 dBi : Theta = 67 Degrees
Perfect Ground : Leg = 10 Meters

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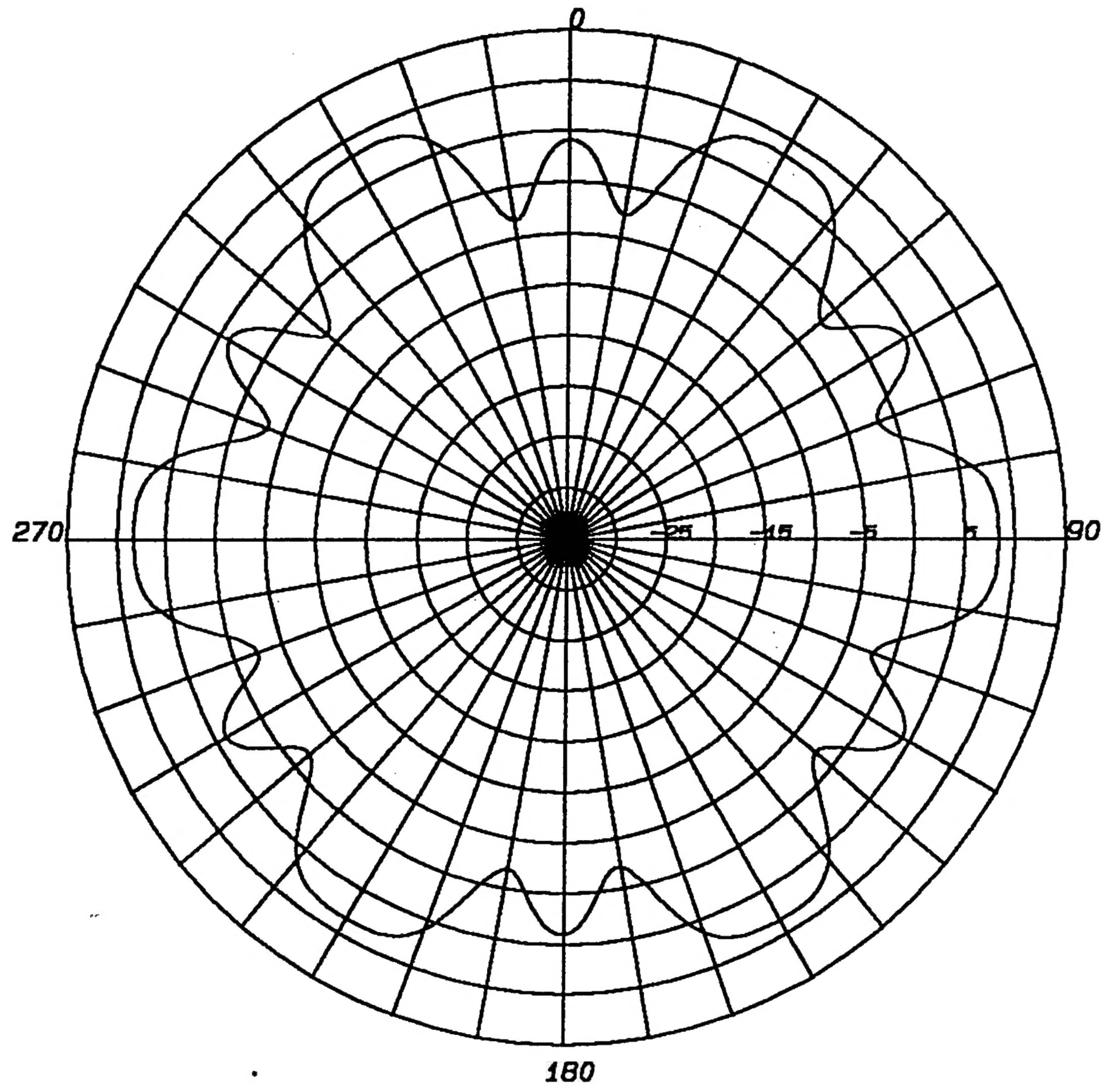
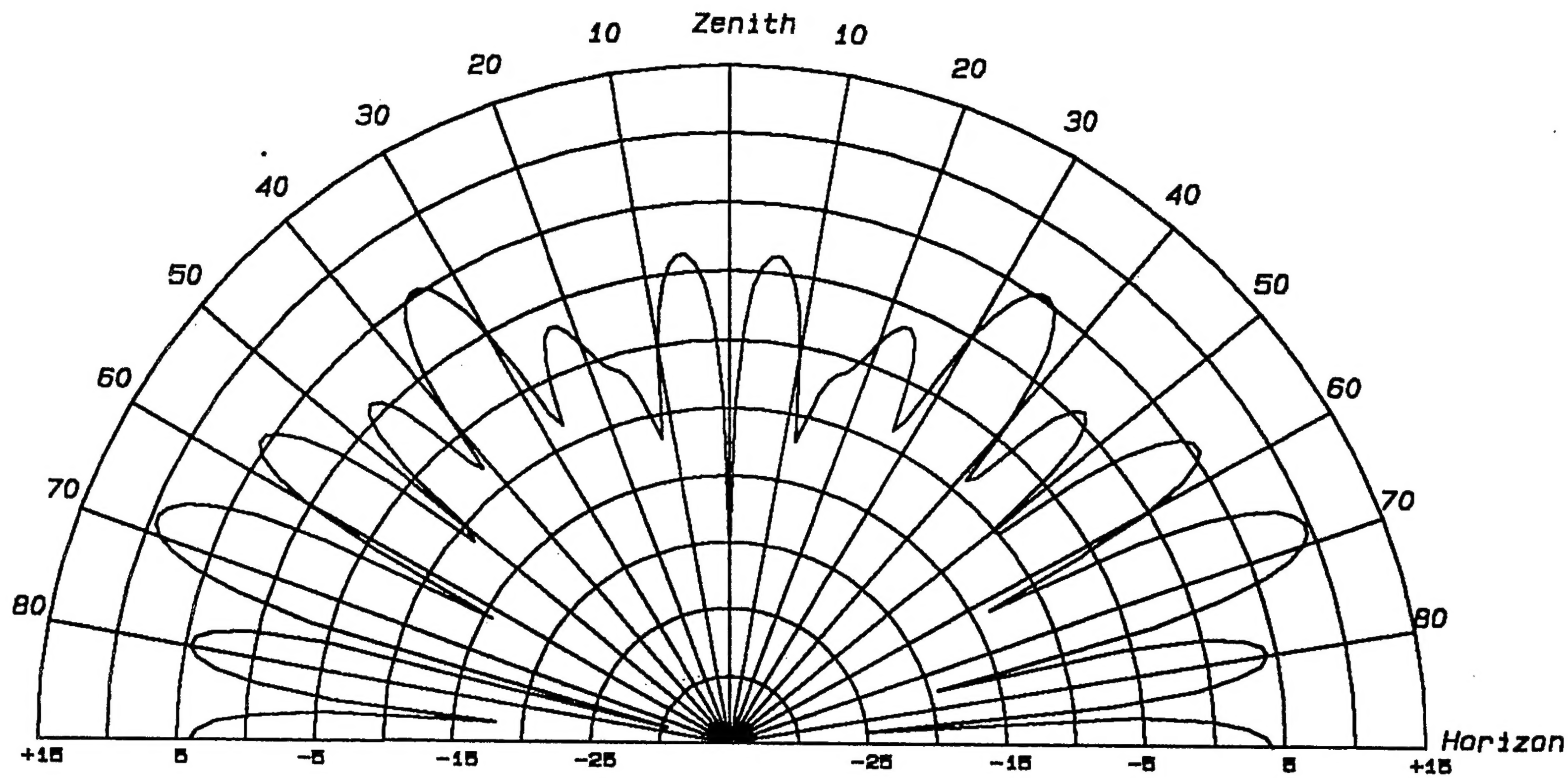
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Azimuth Pattern
Perfect Ground : Leg = 10 Meters
Frequency = 90 MHz : Dielectric Mast
Scale in dBi : Theta = 90 Degrees

Antenna Products Corp.
Mineral Wells, Texas



Six Feed Rhombic Antenna Array Elevation Pattern
Frequency = 90 MHz : Dielectric Mast
Gain = 9.63 dBi : Theta = 68 Degrees
Perfect Ground : Leg = 10 Meters